(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 598 924 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent: 30.09.1998 Bulletin 1998/40

(21) Application number: 93913542.2

(22) Date of filing: 18.06.1993

(51) Int Cl.6: H01F 38/14, B23Q 7/00, B25J 19/00, B65G 43/00

(86) International application number: PCT/JP93/00822

(87) International publication number: WO 93/26020 (23.12.1993 Gazette 1993/30)

(54) NON-CONTACT POWER TRANSMISSION APPARATUS, NON-CONTACT SIGNAL TRANSMITTER, SEPARATION TYPE MACHINE USING THEM AND CONTROL METHOD THEREOF

KONTAKTLOSE LEISTUNGSÜBERTRAGUNGSVORRICHTUNG, KONTAKTLOSE SIGNALÜBERTRAGUNG, MASCHINE MIT GETRENNTEN TEILEN ZU DEREN VERWENDUNG UND DEREN REGELUNGSVERFAHREN

APPAREIL DE TRANSMISSION DE PUISSANCE SANS CONTACT, EMETTEUR DE SIGNAUX SANS CONTACT, MACHINE DU TYPE A SEPARATION LES UTILISANT ET LEUR PROCEDE DE COMMANDE

(84) Designated Contracting States: DE GB

(30) Priority: 18.06.1992 JP 159614/92
15.07.1992 JP 188306/92
07.12.1992 JP 351781/92

(43) Date of publication of application: 01.06.1994 Bulletin 1994/22

(60) Divisional application: 98101894.8 / 0 845 793
98101895.5 / 0 851 441
98101896.3 / 0 845 794
98101897.1 / 0 844 627

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Printed by Jouve, 75001 PARIS (FR)

Description

Field of the Invention

The present invention relates to a transfer mechanism that transfers electric power or signals to an electric load provided in a mobile or rotatable unit and relates to a dividual or split-type mechanical device that employs such transfer mechanisms. The present invention further relates to a control method of the split-type mechanical apparatus.

Background of the Invention

There has recently been a growing demand for autonomic decentralization of a machining system in an entirety of a machine system including robots and machine tools wherein the machining system is divided into independent functional units having control functions and machining functions of their own, i.e., autonomous units, wherein these units, maintaining their independence, carry out a coordinated machine work by effecting communications between a static functional unit (hereinafter referred to as a static unit) and movable functional units as well as mutually between the movable functional units for exchanging commands and information.

Dividing the machining system into a plurality of functional units in this way enables the optimum combinations of a plurality of functional units to fit each particular working object as the occasion demands, and consequently, offers the advantage that a single machine plant may serve for carrying out a wide variety of functions.

However, dividing the processing system into functional units is by no means obvious. For example, determining what extent of the apparatuses within the machining system should be consolidated as one unit presents one technical problem. In addition, it is to be desired that the attachment and removal of each functional unit be easy, and moreover, that an electric power transfer system and a communication system be automatically established between a movable functional unit and the static unit upon attachment of the movable functional unit to the static unit. This is particularly essential in the field of machine tools for realizing complete automatization of operation of jigs and for electrically controlling such operations as positioning, centering, and clamping a workpiece on a pallet as it moves from a setup process to a work process.

In addition, even in the case that a functional unit, for example a servomotor, is not physically separable from the static unit, a way of controlling the servomotor driven on a rotating body making multiple rotations is also becoming desirable. This applies to such cases as, for example, the rectilinear drive of a machine post mounted at the tip of the main shaft of a machine tool by an electric motor, or the electrical powering of a lathe head chucking section, or to a case in which the main shaft of an electric motor is mounted on a rotating index table. In such a case, in order that the control signals and electric power to drive the electric motor is supplied from a static unit, it is necessary that the electric power supply system and communication system always operate stably for any rotations of the rotating body.

A general survey will next be presented of the prior art relevant to the present invention from the viewpoint of the above-described current state of mechanical engineering.

Fig. 1 is a block diagram showing the basic structure of an electric motor control of the prior art.

A power source 11 inputs electric power of commercial frequency and supplies main power supply S12 and control power supply S13 to controller 12. The controller 12, driven by control power supply S13, is composed of position amplifier 12_1, speed amplifier 12_2, differentiator 12_3, current amplifier 12_4, and power switch 12_5, thereby modulating and supplying the main power supply S12 to the servomotor 13 in response to a position command S11 fed from the upstream system. The detector 14 detects the position of the servomotor 13 and feeds back a position signal S15 to the position amplifier 12_1 (position loop). The position amplifier 12_1 generates a speed command from position command S11 and position signal S15. The differentiator 12_3 differentiates position signal S15 and generates a speed signal. The speed amplifier 12_2 inputs the speed signal and speed command and outputs a torque command (speed loop). The current amplifier 12_4 compares the torque command and current signal (current detector value) S14 and modulates the current to be supplied to the servomotor 13 by controlling the power switch 12_5. In this way, control of the prior art of a servomotor is carried out with a servocontroller system including a power source, a position detector and a servocontroller all being fixed based on the premise that any of the constituent parts will not be removed.

In the field of machine tool working, work is carried out for example, by controlling the positioning of a tool post 24 at the end of a main shaft 21 (facer machining center) as shown in Fig. 2, or by chucking a workpiece 34 through chucking jaws 33 driven by a chucking motor 32 at the shaft end of a main motor 31 or spindle unit as shown in Fig. 3 through signal communication with the rotation shaft and through additional power supply other than the rotation power to the rotating shaft. In such cases, however, because the supply of electric power and signals could not be easily achieved in the prior art, methods have been used such as arranging, within a hollow shaft of the main motor 41 or spindle unit, a coaxial shaft 43 for transmitting power in the form of mechanical power, as shown in Fig. 4, but due to problems relating to machining accuracy and long-term reliability, it has been extremely difficult to put this approach into actual use at a low cost. Fig. 4 shows a case in which the mechanical power is used to drive bevel gears 44_1, 44_2 to move a traveling pedestal.

In machine tool working, there has also been great demand for controlling an actuator provided at an end of a main shaft, and otherwise for sending information to a workpiece, jig, or tool at the end of a main shaft, or monitoring the conditions of these components by means of detectors. For example, in a chucking device attached at an end of a spindle head driven with a hydraulic cylinder, because the effective chucking pressure decreases due to the centrifugal force acting on the workpiece as the rotational speed of the spindle increases, it is desirable to effect on-line control through feedback of chucking pressure. Even when actual control of the chucking pressure cannot be realized, there remains a demand for on-line monitoring of the chucking pressure.

In-process monitoring of the state of a tool attached at the end of a spindle head during machining, prediction of breakage of a tool or confirmation of breakage is an essential item for effecting continuous 24-hour processing in FMC. For this reason, it is desirable to have sensor information (for example, information on tool tip temperature, vibration, acoustic emission, etc.) sensed at the main shaft end and returned during machining to an NC control device in real time. It is furthermore necessary to have measured position information on the location ahead of the spindle head (for example, the gap between tool and workpiece), and more basically, feedback of sequence signals such as limit switch signals in an ATC collect chuck.

As explained above, despite the strong demand for obtaining on-line information beyond the main shaft, transmission of the information by wiring cannot be used, because this involves a difficulty of wiring from a part rotating at high speed to a static part. Further, in order to obtain this information reliably, the detectors must in nearly all cases be mounted at the end of the main shaft, and consequently, the detectors must be supplied with electric power from the outside. Mounting batteries at the end of the main shaft to supply power is conceivable but usually not practical due to a large increase in weight of the portion that rotates at high speed as well as to the difficulty of exchanging batteries. Directly coupling a rotary electric generator to the main shaft to obtain power through rotation of the main shaft is also conceivable, but this course would not provide sufficient power when the shaft is at rest or rotating at a low speed. As a result, the necessity remains for some method of of transmitting electric power for the detectors from the static part to the end of the main shaft, and conversely, transmitting detector information from the end of the main shaft to the static part, by way of the high-speed rotating part and independently of the rotating state of the main shaft.

As a method of the prior art, there are examples in which power supply and signal transmission are carried out by arranging slip rings coaxially with the main shaft, but this method has proved impractical in such a case as the main shaft rotates at high speeds of over several thousand rpm, because there is a tendency for problems such as noise generation caused by contact abrasion and poor contact.

In multi-articulated robots and SCARA robots, power supply and signal communication for every output shaft of servomotors have been achieved with a large number of wires, but problems are encountered in that the range of movement of the robot arm is restricted by turn-aside of the wiring and long-term repeated operations lead to fatigue and breakage of the wiring.

Regarding multi-articulated robots, a solution to the above-described turn-aside problem has been proposed in Japanese Patent Laid-open 93-13796. In this multi-articulated robot, a first arm is driven by a direct-drive motor installed in a static shaft. A second arm and a tool shaft are driven by way of pulleys supported by the static shaft, the rotation shaft of the second arm, the tool shaft and rotation transmission means (time belt) linking the pulleys. As to the wiring, a first slip ring is provided around the outside of the direct drive motor for driving the first arm, a third slip ring is provided around the outside of the tool shaft at the end of the second arm, and wiring within the base is connected by way of the first slip ring to the third slip ring through the hollow rotation shaft at the end of the first arm, and further, is connected to the hand through the hollow tool shaft. In this way, the first arm, second arm, and wrist do not interfere with each other and rotation greater than 360° is possible without tangling or break of the wire. However, in this multi-articulated robot, the slip ring is used for the transfer of electric power and signals to the tool shaft.

In addition to the use in multi-articulated robots as described above, contact slip rings have been used for supplying power and communicating signals to multiple-rotation bodies, but here, improvement of reliability is limited by problems of stability and electrode wear during high-speed rotation, and when assembled in a machine, exchange operations are difficult. Furthermore, the adoption of this method of electrode contact is rendered essentially impossible due to problems of maintaining reliable electrical contact when exposed to the metal chips and cutting oil mist present in the working ambience of working machinery.

The non-contacting power transfer apparatus as disclosed in EP-A-0 374 749 has a single magnetic core with a central cylindrical section and a circumferencial annular section. The primary coils connected to the static part are wound radially spaced apart from each other around the central cylindrical section. The secondary coil, which is connected to a rotary unit, is inserted axially into the space defined between the primary coils. The electric power is transferred between the primary and secondary coils electromagnetically intermediated by the magnetic circuit made of the single magnetic core.

In order to insert the secondary coil axially into the space defined in the magnetic core, a gap has to be provided in the magnetic core, through which the secondary

coil is to be passed into the space. This gap causes a leakage of magnetic flux, entailing an inferior transfer characteristic as well as a low transfer efficiency caused by a loss of power to be transferred. In fact, it is known that this type of the power transfer apparatus is capable of transmitting only small electric power. In addition, because the direction of shifting the secondary coil into the space in the magnetic core is limited to the axial direction only, the freedom of choosing the direction of bringing the secondary coil near the primary coil is little. This causes the noncontacting power transfer apparatus to be difficult to employ for static and rotary units of arbitrary shapes and functions.

It is an object of the present invention to provide an electric power transfer apparatus that can supply, without direct electric contact, electric power to a movable or multiple-rotatable body, taking into consideration the above-mentioned problems.

These problems are solved, according to the invention, with the features of claim 1.

Because the magnetic path length of the magnetic circuit does not change despite arbitrary rotations of the rotatable unit, it is rotation-invariant. As a result, the magnetic flux linking with the second coil depends only on the magnetomotive force and does not depend on either speed or the angle of rotation of the rotatale unit. Accordingly, rotation-invariant electromagnetic motive force is generated in the second coil despite arbitrary rotation (multiple rotations, high-speed rotation) of the rotatable unit.

In addition, because the first and second cores secured to the static unit and rotatable unit, respectively, are split across the core gaps, electric power is transferred without direct electric contact, and the rotatable unit can easily be detached and separated from the static unit. As a result, this construction is suitable for power transfer in a dividual or split-type machine apparatus.

In the motor control system of the present invention, regarding the servo-controller for controlling the motor, the portion of the servo-controller that depends on the type of motor is combined with the motor to form an autonomous motor unit, and the portion of the servo-controller that does not depend on the type of motor, i.e., the portion of the servo-controller that can be used universally for any motor, is arranged in the static unit. Further, the portion of the servo-controller that depends on motor type, for example, direct current motors, synchronous motors, or induction motors, is the current controller.

In this way, the autonomous motor unit is made light and compact. Many types of autonomous motor units can be prepared, allowing use of the most suitable unit for attaining an intended object. As a result, autonomous motor units can be used exchangeably while the servo-controller portion provided in the static unit can be used in common regardless of changes of the autonomous motor units.

As described above, the noncontacting power transfer apparatus of the present invention is able to operate stably even for high-speed rotation of the rotatable unit. As a result, by establishing this apparatus between the main shaft and static unit, stabilized power can be supplied to the sensor means arranged at the main shaft tip, and main shaft tip information can be reliably transmitted to the static unit.

According to the method of controlling noncontacting power supply of the present invention, the servo-controller in the static unit generates and provides to an autonomous motor unit a torque command based on both the detected information by the detecting means and the command signal supplied from a prescribed upstream apparatus, and the autonomous motor unit operates the motor in accordance with the torque command sent from the servo-controller portion provided in the static unit.

As described above, the current controller portion of the servo-controller is established in the autonomous motor unit, and the servo-controller in the static unit transmits torque commands to the autonomous motor unit by way of the noncontacting signal transfer apparatus.

Brief Description of the Drawings:

Fig. 1 is a block diagram showing the basic construction of servo-control of the prior art;
Fig. 2 is a view showing the tool post positioning on the end of a main shaft of a motor;
Fig. 3 is a view showing chucking of a workpiece at a main shaft tip of a motor;
Fig. 4 is a view showing a mechanical power transmission mechanism using a coaxial shaft;
Fig. 5 is a view showing the basic construction of a noncontacting electric power transfer apparatus of the first embodiment of the present invention;
Fig. 6 is a variation of the apparatus of Fig. 5 in which magnetic coupling between the primary and secondary coils is strengthened;
Fig. 7 is a view showing a construction for enabling the separation and joining of a U-shaped core and a cylindrical core;
Fig. 8 is a view illustrating an application of the noncontacting power transfer apparatus to addition of a work axis in a machine tool;
Fig. 9 is a view illustrating an application of the first embodiment to addition of a work axis onto a pallet;
Fig. 10 is a view showing the construction of a noncontacting power transfer apparatus of the second embodiment of the present invention;
Fig. 11 is a view showing the construction of the magnetic circuit of the apparatus of Fig. 10;
Fig. 12 is a view showing the construction of a secondary coil of sheet type;
Fig. 13 is a side elevation view showing the arrangement of the rotating disk and U-shaped core of the apparatus of Fig. 10 in a case using a sheet-type

secondary coil;

Fig. 14 is a view showing the construction of a pot-core type high-frequency transformer;

Fig. 15 is a view showing the construction of high-frequency transformer of a rotary-machine core type;

Fig. 16 is a view showing the construction of a rotary apparatus of an other embodiment of the present invention;

Fig. 17 is a sectional view showing wiring within a groove and a hollow portion of the rotating shaft;

Fig. 18 is a view showing the construction of a rotary apparatus of an other embodiment of the present invention;

Fig. 19 is a view showing the construction of a rotary apparatus of an other embodiment of the present invention;

Fig. 20 is an electrical circuit diagram illustrating a manner of providing electric power to an ordinary motor load according to an other embodiment of the present invention;

Fig. 21 is an electrical circuit diagram showing a manner of providing electric power to the controller and detector disposed ahead of a shaft tip according to the twelfth embodiment of the present invention;

Fig. 22 is a block diagram showing a construction of a main-shaft tip information transmission system according to the thirteenth embodiment of the present invention;

Fig. 23 is a view showing the high-frequency transformer structure installed inside the main shaft unit;

Fig. 24 is a view showing the high-frequency transformer structure attached ahead of the tip of a main shaft;

Fig. 25 is a view illustrating a PWM feedback system for information created on a main shaft tip;

Fig. 26 is a view showing the construction of a power source for PWM in the system of Fig. 25;

Fig. 27 is a view showing a multichannel information-transfer path by coaxial arrangement;

Fig. 28 is a view showing an application of the present invention to measurement of a tool tip size of an infeed tool.

Fig. 29 is a view illustrating an application of the present invention to monitoring grasping power of chucking at a main shaft tip;

Fig. 30 is a block diagram showing an embodiment of the split-type control circuit of a servomotor of the present invention;

Fig. 31 is a view showing an example of coupling of autonomous motor units to a servo-controller in a static unit;

Fig. 32 is a perspective view showing a concrete construction of the separable high-frequency transformer shown in Fig. 30;

Fig. 33 is a view showing a circuit for noncontacting transmission of electric power from a static unit to an autonomous motor unit;

Fig. 34 is a view showing noncontacting signal transmission between an autonomous motor unit and a static unit by an optical coupler;

Fig. 35 is a diagram illustrating a multi-channel light signal transfer path of a coaxial arrangement; and

Fig. 36 is a view showing an embodiment of multi-stage connections of the noncontacting power transfer apparatus and the noncontacting signal transfer apparatus;

Detailed Description of the Preferred Embodiments:

As explained above, the present invention relates to a noncontacting power transfer apparatus and various types of machine apparatus using these apparatus. The various embodiments here described appear to cover a broad spectrum at first glance, but all include a noncontacting power transfer apparatus (noncontacting power supply apparatus). These apparatus hold promise of further development for processing machinery, robots, and other machines of the prior art, as will become clear from the embodiments described below. The present invention provides an apparatus having functions further developed through the application of the noncontacting transfer apparatus for electric power of the present invention to various machines. Each of the embodiments hereinafter described realizes the object or, simultaneously, a plurality of the objects of the present invention. The embodiments will be explained in the following order:

1. The noncontacting power transfer apparatus and their applications to installing an additional work axis to a machine tool (Figs. 5-13)
2. The construction of the apparatus for supplying electric power to a rotation shaft and for receiving and supplying signals between the rotating shaft side and the power supply side (Figs. 16-21)
3. A spindle tip information transmitter as the application of Item 3 (Figs. 22-27)
4. Measurement of tool tip sizes of infeed tools and monitoring grasping power of chucking at a main shaft tip as the application of Item 3 (Figs. 28, 29)
5. A servomotor and its split-type control circuit (Figs. 30-35)
6. Multi-stage connections of noncontacting power transfer apparatus and noncontacting signal transfer apparatus

Fig. 5 shows the basic construction of a first embodiment of the noncontacting power transfer circuit of the present invention, (A) being a structural view, and (B) being a plan view.

A magnetic circuit (hereinafter referred to as a magnetic path) is made up of a fixed (static) U-shaped core 51, and a rotating core 53 of cylindrical shape inserted in taper holes 52 in the fixed core 51. A primary coil 54

is wound on fixed core 51, and a secondary coil 55 is wound on rotating (rotatable) core 53. For both coils litz wire is used for improved high-frequency characteristics. Because the terminals of secondary coil 55 must be taken out onto the rotating body, the lead wire is passed through lead-in holes 56, through the interior of the rotating core and out through upper lead-outs 57. By virtue of this construction, when rotating core 53 makes multiple rotations relative to the static part, any disturbances in the magnetic field and any variations in the effective magnetic path length are not caused, because such multiple rotations correspond to a sufficiently low electric frequency as compared with the high excitation frequency. Consequently, stable supply of electric power is possible in case there is no variation in the gap length of the slide portion due to the rotation.

Fig. 6 shows the construction of a modification of the apparatus of Fig. 5 in which the leakage in magnetic flux is reduced and coupling of the primary and secondary coils is strengthened. Specifically, in the structure of Fig. 6, the U-shaped core 61 is attached to the rotatable unit, and the cylindrical core 63 is secured to the static unit. Further, in order to strengthen the coupling between the primary coil and the secondary coil, the cylindrical core 63, on which the primary coil is wound, is covered with a mold-formed secondary coil 65 arranged so that the secondary coils will not contact with the primary coil. The formed secondary coil 65 is tightly fixed to the rotatable unit, and the electromagnetically induced voltage in this coil is supplied to the rotatable unit. In this construction, because the U-shaped core 61 is not a support of the secondary coil but rather serves to close the magnetic path, a construction is preferred in which the core 61 moves so as to fit to the slide surface in order to reduce the gap to the utmost. This object cannot be achieved if the core is secured tightly to the rotatable unit, but since there is no need to rigidly secure the core 61 in this construction, the U-shaped core 61 is loosely secured to the rotatable unit by loose joining members 66 so that the joining will not hinder rotation. In this way, the core is automatically attracted to the cylindrical core 63 by the magnetic attractive force and itself moves so as to reduce the gap, thereby acting, with the effect of the overlap winding of the secondary coil above, to realize electromagnetic coupling with little leakage of magnetic flux.

Fig. 7 shows the construction for separating and joining the U-shaped core and the cylindrical core 73, (A) showing the construction and (B) showing the joining and separating procedure.

As shown in the figure, on each of two parallel extending legs 71 of the U-shaped core, which is the fixed (static) portion of the construction in Fig. 5, a notch 74 is formed reaching from the end of the leg to the tapered hole 72 to produce an open form, resulting in a construction that allows the rotating body and the fixed portion to join or separate along the direction perpendicular to the axis of rotation of the rotating body, and this construction has useful possibilities for the structure of the machine system of the present interest. Specifically, as shown in the same figure, the power transfer apparatus is constructed and split in the order of coupling, power supply to the rotating body and decoupling, thereby allowing detachment as well as multiple rotations of the rotating body.

Fig. 8 shows an example of establishing an additional work axis in a machine tool (machining center) in which the power transfer apparatus of the type shown in Fig. 5 or 6 is advantageously used. (A) shows the state before establishing the additional axis to the pallet, and (B) shows the state following the establishment. Here, reference number 81 indicates a machining center having a rotating table 82 and a pallet 83, to which is attached a workpiece which can be worked on the four surfaces excluding the upper and lower surfaces. The pallet 83 to which the workpiece is clamped can be attached to the rotating table 82 through a pallet exchange operation, and if the functions of a vertical rotating table 86 is established on this pallet as shown in the figure, freedom of working can be increased significantly by allowing work of five surfaces. For this purpose, a servo-axis is mounted on the pallet (the servo-spindle is built in the rotating table 85). Upon exchanging the pallet 83 preceding the commencement of cutting, automatic power supply must be effected. However, this power supply cannot be effected through contact-type connection as is carried out in the normal environment, because contact-type power feed requires simultaneous multipolar (two or more points) contact, and due to difficulty in positioning, such automatization is difficult. Furthermore, power feed by electrodes is virtually impossible in the work area of a machining center because of the difficulty of maintaining good electrical contact in an ambience of metal chips and cutting oil.

The application of high-frequency electromagnetic induction to power feed according to the present invention is therefore proposed. This offers advantages in that power transmission can be continuous in analogue wise and precise positioning or fitting is unnecessary, and further, it is relatively impervious to severe conditions. For example, even if the cutting oil used in a machining center is water soluble and highly conductive, the occurrence of an eddy current will not reach a level that can influence the power transmission characteristics, meaning that exposure to cutting oil will scarcely impede transmission. In addition, despite concern that metal chips created by cutting a workpiece may attach to the magnetic path and cause transmission loss due to the generation of eddy currents, in actuality, even with chipped magnetic powder disposed to adhesion due to attraction, the adhesion will not occur as long as the residual magnetic flux of the magnetic core is not large because the excitation frequency is high and, moreover, the polarity of magnetization alternates. Even if adhesion were to occur due to some other factor, cutting oil could be used effectively to wash away the offending

material.

In Fig. 9 is shown a construction using a rotatable power transfer method that allows separation and coupling for realizing the work-axis addition shown in Fig. 8. (A) shows the fixed core 91 and rotating core 93 before mount by movement of the pallet 90, and (B) shows the state in which the fixed core 91 and the rotating core 93 are in a fitted state and power is supplied to the added axis (the servomotor for the added axis). As shown in the figure, through an arm 92 extending from the static part of the machining center, the fixed core 91 is accurately positioned in the vicinity of the rotation center of the rotating table. The rotating core 93 is arranged on the rotation axis of the pallet, and the lead wire from the secondary coil wound on the rotating core 93 is led into the pallet. As explained above, in automatic exchange (from (A) to (B) in the figure), because the pallet and rotation table are joined such that the axes of rotation coincide, a power transfer apparatus can be constituted in the form shown in Fig. 7. Even if the table rotates through indexing, power supply from the static machining center to the pallet can be continuously effected free of influence by the angle of rotation. The servo-spindle and servo-controller are provided inside the pallet, and the high-frequency voltage induced in the secondary coil is converted to DC voltage by the rectifying-smoothing circuit embeded in the pallet and used as main power and control power of the servo-controller. Moreover, control of the added work-axis and feedback of signals are carried out by a method not shown in the figure (for example, by high-frequency electromagnetic induction according to the same principle as the power transfer, or optical transfer such as by infrared light).

In this way, the application of high-frequency electromagnetic induction solves the problems of instability and abrasion encountered during high-speed rotation in the contact-type (slip ring) power supply of the prior art, and in addition, power can be transmitted to a multiple-rotating body free from the influence of the interposition of cutting oil or cut chips occurring in the operating environment of machine tools.

Accordingly, an apparatus is achieved that has an increased transmission efficiency, allows use even under the severe conditions of such as a machine tool environment, and effects power supply without direct electric contact even between bodies that are not only rotatable, but also separable and joinable relative to each other, and as a result, automatic exchange can be easily carried out, for example, between cutting work pallets, work tools, and heads in machine tool work, thereby contributing to the acceleration of automatization in manufacturing applications for limited-quantity large-variety production.

Fig. 10 shows a construction of the second embodiment of the noncontacting power transfer apparatus of the present invention. Fig. 11 shows the construction of the magnetic circuit of the apparatus of Fig. 10, (A) being a case where the periphery of the rotating body is a non-magnetic substance, and (B) showing a case in which the periphery is a high-frequency magnetic substance.

An electrically insulating substance (non-magnetic substance) 102 is applied to the periphery of the rotating body 103, which is the object for power supply, and around this substance the secondary coil 105 is circumferentially arranged. Opposed to this assembly, a U-shaped high-frequency magnetic core (U-shaped core) 101, around which the primary coil 104 is wound, is arranged in a static part outside the circumference of the rotating body 103 so as to straddle the insulating substance 102 and the secondary coil 105. The end lead wire passes through a lead-out hole 109 and is led out towards the rotation axis so that the U-shaped core 101 does not contact the secondary coil 105 even when the rotating body rotates in relation to the static part. The primary coil 104, under excitation by means of a high-frequency inverter 106 in the static part, gives rise to main magnetic flux passing through the U-shaped core 101 and the insulating substance 102. Here, the width W of the insulating substance 102 is within a range sufficient for providing the electrical load capacity required to the rotating body but is made as thin as possible to suppress magnetic flux leakage to a low level. However, as will be explained below, this limitation is not necessary for a case in which the magnetic path is closed by making the part of the insulating substance 102 with the same magnetic material as the U-shaped core. In addition, when it is necessary that the rotating body be removable, the widths of both the insulating substance 102 and the secondary coil 105 are made smaller to allow removal from the U-shaped core.

In the secondary coil 105, high-frequency voltage occurs due to electromagnetic induction, and when the circuit of the secondary coil 105 is closed through the electrical load on the rotating body, current flows in order to compensate for a change in the magnetic flux produced by the primary coil (shown in the figure). As a result, the secondary induction voltage taken out onto the rotating body through lead wire lead-out hole 109 is thus supplied to an electrical load such as a motor or solenoid through voltage converter circuit 107 and the stabilizer circuit 108 on the rotating body as well as is used as power source for an information transmitter or detector not shown in the figure.

Here, in cases when the material used for electrically insulating substance 102 is not a magnetic substance (in particular, a high-frequency magnetic material), magnetic flux leakage occurs in the magnetic path produced by the primary coil as shown in Fig. 11(A), but such a material may still serve for applications that allow some transmission loss (transfer loss) by keeping the width of the insulating substance 102 to the utmost minimum, as explained above. Accordingly, within the range of low-power transfer, it is advantageous to construct the insulating substance 102 and the secondary coil 105 as a print substrate and sheet coil as shown in the plan view of Fig. 12. Fig. 13 is a side elevation view showing

U-shaped core and the rotating body with the secondary coil formed in a sheet coil.

For applications that do not allow transmission loss due to magnetic flux leakage, the peripheral part of the rotating body 103 can be made of the same high-frequency magnetic material as is used for the U-shaped core 101. This is realized by arranging a ring-shaped core 111 around the periphery of the rotating body 103 so as to form a part of the magnetic path, as shown in Fig. 11 (B).

However, since both of the cases illustrated in Fig. 11(A) and (B) assume noncontacting power transfer, the existence of an air gap, however small or large, gives rise to leakage of magnetic flux, and it is therefore necessary to in some way arrange the structure to reduce this gap to the minimum.

In whatever case, in contrast to the contact-type transfer, power transfer by the above-described power supply method is superior because it is effected continuously in analogue wise, and because neither precise positioning nor fitting is necessary, and in addition, this method is advantageous in that the power transfer apparatus can stand up to severe conditions. For example, exposing the apparatus to cutting oil in the working environment of a machine tool will scarcely impede the power transfer. Further, despite the concern that adhesion of cut metal chips to the magnetic cores or air gap will cause transmission loss due to eddy currents, in actuality, because of the high excitation frequency and the alternating polarity, even adhesion by magnetic chips will not occur as long as residual magnetic flux is not large. Even should adhesion occur for some other reason, cutting oil may be used effectively to wash away the offending material.

According to the present embodiment, noncontacting power supply can be effected by merely arranging the secondary coil in the peripheral part without altering the structure of the rotating body itself. Further, an apparatus is realized that allows not only rotation but separation and joining, and which can operate in severe conditions wherein the apparatus is subjected to fouling by cutting oil and metal chips present in the working environment of a machine tool.

As a result, improved machining functions on an already existing multiple-rotation body (such as a round table) can be readily achieved. Such an apparatus is useful in, for example, realizing automatic establishment of an additional servo axis on a cutting work pallet and automatic exchange of work tools and heads in machine tool work, thereby contributing to the acceleration of automatization of manufacturing applications for limited-quantity large-variety production.

In regard to the frequently cited noncontacting power transfer apparatus of the following embodiments, simple explanations will be given of the technology of the prior art. There are cases using a pot-core as in Fig. 14, or a rotary-machine type core as in Fig. 15. In the case of a pot-core, a pot-core 140 on which is wound a primary coil 141 is made to confront a pot-core 140 on which is wound the secondary coil 142 with a gap therebetween, and power is transmitted by means of electromagnetic induction. Both of these pot-cores are of a high-frequency magnetic substance. Because this type is of flat-form structure, when provided within a motor or reduction arrangement, the design of the apparatus is little influenced by the enlargement of the form in the direction of the rotation axis, but as shown in Fig. 14 (B), the magnetic path is in the direction of the rotation axis, meaning that the magnetic flux that passes through the core tends to be limited by the upper limit of the magnetic flux density in the core material (the saturation characteristic). In another rotary-machine type core having a coaxial form in which another core is inserted inside the cylindrical core 150 (refer to Fig. 15A) in the same relation as the rotor and stator of a rotary machine, the magnetic path becomes perpendicular to the direction of the rotation axis, as shown in (B) of the same figure, with the result that the dimension of the axial direction of a motor or reduction arrangement incorporating this type of the core may increase, but with the advantage that, similar to normal motors, the magnetic flux per unit volume can be increased and a higher overall power rate (transmission power per unit volume) can be obtained. However, this type also requires that the electrical angle of one of the cores be skewed as shown in Fig. 15A in order that the magnetic path length does not change depending on the rotation angle. In the same figure, a skew has been applied to the inserted core.

All of these apparatus are split-type high-frequency transformers in which the primary coils 141, 151 (static side) of the split-type high-frequency transformer Tr are excited by means of high-frequency (sine wave or rectangular wave) inverter, and high-frequency voltage is produced by electromagnetic induction in the secondary coils 142, 152 (rotatable unit) that oppose across a slight distance. Here, the distance between the primary and secondary cores of the split-type high-frequency transformer Tr is made as small as possible to reduce the power loss due to the interposing air gap.

Further, although the primary and secondary cores may rotate relatively around the same axis, because there is no actual disturbance in the distribution of the magnetic field when the equivalent electrical frequency is below the above-described high-frequency excitation frequency, no time variation will occur in power transfer characteristic during rotation or stopping.

Fig. 16 shows the construction of an other embodiment of the present invention, which is an example incorporating a power coupler and a signal coupler within the case of a main shaft servomotor (or more widely, electric motors in general). Fig. 17 is a figure showing the ways of lead-out of the signal lead-out and the power lead-out from the end of the shaft, Figs. 17A and 17B showing lead-out through a hollow hole and lead-out through a groove, respectively.

In the same figure, within the case of the motor

made up of a stator 223 and rotor 224, a primary core 221 which is a high-frequency electromagnetic induction core is arranged near the bearing on the static side, and a secondary core 222 is provided on the rotation shaft 220 opposing the primary core across a gap, and the primary and secondary cores form the previously described split-type high-frequency transformer. The coil of the primary core 221, similarly to the stator 223 of the torque (motive power) generator part (TGP), is excited through the power line, and the coil output of the secondary core, by way of the lead-out 229 that passes through a groove 231 in the rotation shaft 220 or a hollow portion hole 230, is led out to the tip of the rotation shaft (refer to Fig. 17). In the opposite side of the load with respect to the power transfer part (PTP) and torque generator part (taken together as the *power* transmission section), an information transfer section (ITS) is arranged through the bearings. Parts 225, 226 make up either optical or high-frequency electromagnetic induction communication couplers for signal transfer, one side being provided on the static side, the other being provided on the rotating shaft side, either side being the transmission side or the reception side as the case demands. The signal communication of the electric load provided at the shaft tip are achieved by the signal lead-out 228 that passes though a groove 231 in the rotating shaft or a hollow portion 230 (See Fig. 17). In Fig. 16, signal couplers 225, 226 are provided in a plurality of pairs, but in this case, each of the pairs must be shielded in order that they not be influenced by leakage of optical signals or electromagnetic induction signals from other pairs. Such shielding is not important, however, in a case in which peak wavelengths in the response spectrum of a plurality of optical couplers used differ greatly for each coupler. The power source of a sensor (for example, an encoder for position detection) 227 for a motor of the prior art that is built into the motor may also be used for the power supply of the above-described signal coupler, and in addition, the signal processing such as wave-form shaping of the coupler output may also be carried out in the signal processer for the sensor of the prior art.

Figs. 18 and 19 show another embodiments according to a similar concept in which a power transfer part and signal transfer part are incorporated within the case of a reduction arrangement, Fig. 18 showing a case in which the input shaft and output shaft are not coaxial, and Fig. 19 showing a case in which these shafts are arranged coaxially. Regarding Fig. 18, the rotation of motor 247 is reduced and transferred to output shaft 242 by way of gear train 241 provided within the casing. The output shaft 242 is supported at both ends by the bearings on both sides of the casing of the reduction arrangement, and between the bearings is attached the secondary core 244 of the split-type high-frequency transformer and the receiving section 246 of the signal coupler, the lead-outs 248, 249 being led to the electric load provided at the output shaft end by way of a groove or a hollow portion in the output shaft 242. On the inner face of the case, the primary core 243 of the split-type high-frequency transformer and the transmission section 245 of the signal coupler are provided in positions opposing across a gap the secondary core 244 and receiving section 246, respectively, on the output shaft side. Regarding Fig. 19, the only points of difference from Fig. 18 are that the input and output shafts are arranged coaxially and that harmonic gear (precession gear) 252 are used for the reduction stage. In either case, the operation is similar to the case in which the components are incorporated into a motor: the power transfer part and the signal transfer part are attached to the output shaft, and the wirings 258, 259 for these parts are led out to the electric load provided at the shaft end through a groove or a hollow portion in the output shaft (See Fig. 17). Moreover, the order of positions on the shaft of the power transfer part and the signal transfer part may be interchanged.

Next will be explained, referring to Fig. 20, the method of transmitting power and signals to an electric load installed at a rotating output shaft tip to drive the load using a motor or reduction arrangement unit constructed in such a manner that allows transmission of the power and signals to the output shaft tip, as described above.

In a case in which the electrical load is a light-generating or heat-generating load, because either case is of an effective value load, the high-frequency voltage received at the shaft end lead-out may be applied as is to the load. The shaft end lead-out voltage may also be applied as is when driving a high-frequency motor. However, in the case of general motor loads, in order to drive in a DC or low frequency range, a high-frequency rectification circuit 263 (made up of a diode and an LC filter) must be mounted ahead of the shaft tip to convert to DC or low frequency voltage (embodiment 11). This DC voltage is then used to (1) voltage-control the DC motor 264, and (2) control the load 266 through a bridge 265 of power switch elements such as transistors.

In this way, any of DC motor, a synchronous motor, or an induction motor can be controlled at a position beyond the rotating shaft end. It is not necessary, however, to mount all components of a servo-controller of the prior art at the shaft end. This is because, as described above, transmission of a signal (for input and output) can be effected between the static side of a motor or reduction arrangement and the output shaft end by means of noncontacting transfer, and if, for example, the position information and speed information obtained at a sensor mounted on a motor attached beyond the shaft end is returned to the static side by means of this transfer channel and torque command information is sent from the static side to the shaft end side by means of another signal transfer channel, position and speed control for the motor control can he carried out at the static part and torque control can be carried out at the position beyond the shaft end. In this way, a method can be employed that enables reduction of the weight and physical

size of controller parts attached at positions beyond the end of a shaft end.

The power source for a controller part or detector arranged beyond the shaft end is supplied with the transmitted power after the above-described rectification following stabilization by passing through an automatic voltage regulator (AVR) 273, as shown in Fig. 21.

The above description focuses on a case in which work is performed by mounting an electric load beyond the shaft end and using transmitted power. The present invention, however, is also effective in an application limited to applying a low electric power (or in some cases, applying no electric power) to the device disposed beyond the shaft end to operate a sensor, and transmitting its signal to the static part. In this case, the previously described power transfer part can be extremely small (or nonexistent).

Further, although the high-frequency induction power transfer of Fig. 16, Fig. 18 and Fig. 19 is carried out in single phase, the power transfer may also effectively be made in polyphase for one or a combination of the following reasons: 1) to increase transmitted power, 2) direct control of a high-frequency motor or stepping motor, 3) to reduce the burden on a rectification circuit.

The above-described power and signal transfer elements can be integrated by incorporation within a motor or reduction arrangement, thereby

1) suppressing the generation of output shaft rotational vibration by incorporating the rotating part of the element (particularly the heavy power transfer part) between the bearings;
2) facilitating control of the gap in the noncontacting power transfer part and control of the ambience of the gap (preventing fouling by dust and the like);
3) in particular for a signal transfer part using optical coupling, controlling the ambience in the same manner as for an optical encoder of the prior art; and
4) rationalizing the structure by, when incorporating into a motor, combining the motor torque generator part of the prior art with the above-described power transfer part en bloc as the power transmitter section, and controlling the ambience by combining the sensors such as optical encoders in the prior art motor and the above-described signal transfer part en bloc.

The embodiments include all applications, not only to the field of precision motor control such as a knucle in each axis of the previously described robot arms or machine tools (particularly for the drive at the tip of a main shaft), but also to the wide range of fields that require power supply and information transfer through a rotating part and that have hitherto required wiring and slip rings giving rise to the problems of fatigue and wear.

The present invention enables power transfer and signal transfer through a rotating part which were not feasible in the prior art, and moreover, by incorporating the noncontacting transfer part into a motor or reduction arrangement (particularly when incorporating with a motor), treating the torque generator part and the power transfer part together as a *power* transmission section, and treating the sensors and signal transfer part together as the information transmission section, the invention both allows stabilization of the structure of the rotating part and enables the control of the gap and ambience by isolating these transmission sections from the outside ambience.

Further, passing wiring for power transmission and signal transmission through a groove or hollow portion of the output shaft allows disposition of wiring that does not affect the transmission of motive power, and in addition, the grounding of the output shaft through the bearings allows a potential shielding effect for the wiring, and the influence of noise released to the outside or received from the outside can be dramatically reduced.

Further, because sensor information can be obtained from the shaft end by way of the signal transfer part, by using the present invention combined with the mechanical power transmission (for example, in Fig. 4) of the prior art, the present invention can be used to control mechanical power transmission.

By using a combination of a plurality of motors or reduction arrangement in which are incorporated power and signal transfer structures constructed in this manner, a mechanism (machine tool, robot) that enables easy attachment, detachment and exchange can be easily constructed without wiring .

A main shaft end information transmitter according to the an other embodiment of the present invention will next be described. In this embodiment, the sensing and transmission of main shaft tip information is achieved by combining noncontacting power transfer using high-frequency electromagnetic induction with information transfer using the EIC coupler or optical coupler.

Fig. 22 shows the fundamental structure of noncontacting power and information transmission according to the present embodiment. As shown in the figure, a power coupler 283 of split-type high-frequency transformer Tr structure is either built into the main shaft unit or attached to the main shaft tip. On the left side of the figure are placed a high-frequency inverter 281 and an information receiving circuit 282. The power outputted from the high-frequency inverter 281 is transmitted to the rotatable unit by way of the power coupler 283, and after being rectified and stabilized by the rectification-smoothing circuit 286 and the stabilizing circuit 288, is supplied as power source to the sensor 289. The coupler drive circuit 287 is supplied with power from the output of the stabilization circuit 288 and drives the optical coupler 284 and electromagnetic induction communication coupler (EIC coupler) 285 in response to sensor information S_T fed from the detecting end (sensor) 289. The information receiving circuit 282 receives and processes the outputs of the optical coupler 284 and the EIC coupler 285 (on the static side). Fig. 23 shows a high-

frequency transformer Tr construction incorporated within a main shaft unit in which power transfer is effected by means of electromagnetic induction generated between high-frequency magnetic substances of pot-core type placed face to face. In this case, the secondary side pot-core 292 is fixed coaxially to the main shaft 290, and the main shaft 290 is driven by a main shaft motor 297 by way of a timing belt 296. The primary side pot-core 291 is fixed to the main shaft motor 297. When the primary coil 293 is excited, induced power caused in the secondary coil 294 by way of the primary and secondary pot-cores is sent to the tip of the tool 298 via the secondary coil lead 295.

Fig. 24 shows a case in which a high-frequency transformer Tr construction of a power coupler is attached to a main shaft tip, Fig. 24A being a schematic view showing the attached position, and Fig. 24B being a plan view showing the arrangement of the power coupler (the noncontacting power transfer apparatus) as viewed from the tool side. The power coupler is of the same form as the first embodiment, with the U-shaped core 301 fixed to the static part and the core ring 303 of a high-frequency magnetic substance fixed around the circumferential edge of the tip of the main shaft 209 coaxially with the main shaft 290 forming a magnetic circuit together with U-shaped core 301.

In either construction, the primary coil 293 of Tr is fixed on the static side, is excited at a high frequency, and generates a high-frequency voltage corresponding to a turn ratio on the secondary side. The secondary side, on which is arranged the secondary coil, is attached to the main shaft side and consequently rotates at a speed corresponding to the main shaft rotation speed relative to the primary side. Either of the cases shown in Fig. 28 and Fig. 29 uses a construction such that the gap width between the primary and secondary cores does not vary over one rotation of the main shaft. Here, if high-frequency excitation is effected at a high frequency equal to or greater than 10kHz, the frequency of the excitation is sufficiently high compared to the maximum rotation frequency of the main shaft reduced to an electrical angle, whereby even should the main shaft rotate at high speed, no substantial disturbance will occur in the magnetic field distribution, and stable power transmission can be performed so far as no change is caused in the gap between the high-frequency magnetic cores of the primary and secondary coils.

Because it is necessary that the power source for the sensor provides sufficiently stable voltage, the DC voltage obtained by rectification and smoothing of the high-frequency voltage produced by secondary coil induction is supplied to the sensor after stabilized through a stabilizing circuit, as shown in Fig. 22. With this power source, the sensor detects the physical values at the rotating main shaft tip and generates sensor information. When the sensor information (signal) is a digital signal of a pulse train, it is amplified and supplied directly to the signal transfer circuit described below. As shown in Fig. 25, when the sensor information is of an analog signal, the analog signal is also converted to a pulse train signal by pulse width modulation (PWM) that modulates a saw-tooth wave carrier signal produced from the voltage to be sent to the main shaft tip by way of the high-speed rotating part (in power coupler), i.e., the output voltage of the stabilizing circuit 288. In particular, when a detected analog signal varies with positive and negative polarities, the saw-tooth wave must also be converted to be bipolar. In such a case, in order to simplify the power circuit on the main shaft tip, a combination of the secondary coil and rectification circuit as shown in Fig. 26 is used. The device shown in Fig. 25 is the device in which a PWM modulation circuit 311 is added to the device of Fig. 22, and V^+ and V^- are voltages for generating saw-tooth waves that change between positive and negative values (Refer to Fig. 26). PWM modulation circuit 311 modulates the saw-tooth carrier signal by the analog sensor information S_T and generates a PWM modulated wave S_{PWM}. Fig. 26 is a block diagram of the rectification-stabilization circuit (corresponding to the rectification-smoothing circuit 286 and the stabilizing circuit 288 of Fig. 25) for generating the positive and negative voltage necessary for generating a saw-tooth wave that changes with positive and negative polarities.

In this circuit, the secondary coil of the split-type high-frequency transformer 321 that makes up the power coupler has an intermediate tap, and this intermediate tap is connected to the ground potential of the rotatable unit. The output of the split-type high-frequency transformer 321, after being rectified and smoothed by diodes D_1, D_2 and capacitors C_1, C_2, is stabilized by voltage stabilizing regulators AVR1, AVR2, AVR3, and outputted by way of output capacitors C_3, C_4, C_5. Voltage V_1 is used as the power source for sensor 289, and V^+, V^- are inputted to PWM modulation circuit 311 as described above.

A sensor signal that has been converted to a pulse signal in this way is transferred without direct contact to the static side by high-frequency induction transfer or light pulse transfer beyond the high-speed rotating part by way of the central or exterior route of the above-described transformer Tr for *power* transmission. On the static side, light or high-frequency pulses are received and undergo digital-to-analog conversion as necessary. In particular, a PWM modulated signal can be demodulated to an analog signal by merely passing through a low-pass filter on the static side.

When the sensor signals are generated in a plurality of channels, information transmission paths for each of the channels can be structured in a coaxial arrangement as shown in Fig. 27 (this is an example using optical couplers) or by attaching a microcomputer to the secondary side, i.e., the main shaft tip, and sending data for the plurality of sensors by a single information transmission path in the form of serial data with designated channel numbers. Fig. 27 shows a three-channel optical coupler, Fig. 27A being a light-emitting part and Fig. 27B

being a light-receiving part. The light-emitters 331, 332, 333 are coaxially arranged around the rotating axis 330 with an optical shield 335 arranged between each emitter. As light-emitters 331-333, any of the electric-to-light converters disclosed in the third, fifth, and seventh embodiments can be employed. The light-receiving elements 336, 337, 338 are arranged so as to confront each of light-emitters 331, 332, 333, respectively, when the rotating shaft 330 is fitted in the bearing 339.

The present embodiment enables the acquisition of information from the rotating main shaft or main shaft tip not possible by the prior art, thereby enabling the on-line monitoring of a state on the rotating main shaft as well as enabling closed loop control by feedback of the main shaft tip information in lieu of open loop control of the prior art.

Fig. 28 shows an example of remote measurement of a tool tip dimensions of an infeed tool 340 for variable-radius boring attached to a main shaft. As shown in the figure, a coaxial shaft 341 for motive power transfer arranged coaxially with the main shaft is passed through a hollow main shaft fixed within a main shaft unit 343 and delivers from a distance the motive power of a servomotor by way of a mechanism such as bevel gears 342a, 342b, thereby directly moving a tool tip in a tool post 344 and changing the boring radius. In this example, however, the tool tip dimensioning is carried out by open loop control because in this construction, the tool tip is mechanically moved by the servomotor of the motive power source by way of such a complicated structure. As a result, tool tip dimensioning requires the worker to stop the rotation of the main shaft for every process and check the dimension by measuring it with a scale. In contrast, by measuring tool tip dimensions with a linear scale 345 at a part ahead of the main shaft and feeding back the measured values to the static part using the present invention, measurement of a remote tool tip dimension can be achieved while rotating the shaft, and consequently, change of boring radius can be effected in process by closed loop control. As shown in Fig. 28, the power sources for the signal processing and communication circuit 348 and for the linear scale 345 are supplied by rectification-smoothing circuit 347 by way of a pot-core power coupler. The communication circuit 348 converts the output of the linear scale 345 to a pulse train and transmits it to the static part by way of the optical coupler 349 made up of light-emitting element 349a and light-receiving element 349b.

In the same way, use of the present invention also enables on-line monitoring during operation of tools required in 24-hour continuous processing in FMC (for example, prediction of tool breakage and confirmation of breakage based on acoustic emission information, tip temperature information and vibration information).

Further, the invention allows easy feedback of measured information of a position beyond a spindle head (for example, the gap between a tool and a workpiece), as well as of the more basic sequence signals such as limit switch signals of an ATC collect chuck. For example, in a chucking apparatus mounted at a spindle head tip that is driven by a hydraulic cylinder, because actual chucking pressure varies with the increase in rotation speed of the spindle, it is desirable to effect on-line control by feedback of chucking pressure. On-line monitoring of chucking pressure is desired even when actual control is not intended. In such a case, monitoring can be achieved as shown in Fig. 29, in which a pressure sensor (such as a device applying a piezoelectric element) 353 attached to a part where the workpiece 351 contacts the chuck 342 is used to detect variation in the grasping power exerted on the workpiece, and this information is sent to the static side by the data transmission method of the present. The hydraulic actuator 345 shown in the figure is driven by hydraulic pressure applied from a rotating cylinder 355 by way of rotating coupler 356. Power supply for the signal processing circuit 358 is effected by using rectification-smoothing circuit 357 to rectify and stabilize a high-frequency voltage transmitted from the static part by way of a pot-core power coupler 357a. The signal processing circuit 358 converts the output of pressure sensor 353 to a pulse train and transmits it to the static part by means of an optical coupler 359 made up of light emitting element 359a and light receiving element 359b.

The present embodiment is not limited to the above-described periphery of a machine tool main shaft, but can also be generally applied effectively to the measurement of physical values on a rotation shaft of an electric motor that has been beyond the capability of the prior art, and as a result, is useful in improving the capability of controlling motors, particularly servomotors. For example, direct detection of motor shaft vibration is essential for improving the control characteristics of servomotors. For such detection, a strain gauge is adhered to suitable points on a motor rotation shaft, the analog output voltage of the bridge circuit is amplified, the PWM conversion is effected, and the occurrence of shaft vibration can be detected on line in the form of stress of the shaft by way of the rotating part using the construction of the present embodiment. Measurement of rotor temperature necessary for vector control of an induction motor can also be achieved on line through the method of the present embodiment.

Fig. 30 is a block diagram showing a separate-type control system for a servomotor of an other embodiment of the present invention.

The present embodiment is composed of a static unit side servocontroller 361 constituting a static side, an autonomous motor unit 364 which is a separable mobile side and is a machine element for autonomous decentralization, and a split-type high-frequency transformer 362 and couplers 363_1, 363_2 that perform non-contacting power supply and signal transfer between these two sides.

The static unit side servocontroller 361 is made up of a power source 361_1, high-frequency power genera-

tor 361_2, position amplifier 361_3, differentiator 361_4, and speed amplifier 361_5. The autonomous motor unit 364 is made up of a rectification circuit 364_1, a voltage stabilizing converter 364_2, a power switch 364_3, a motor 364_4, a sensor 364_5, a current amplifier 364_6, and a current command generator 364_7.

In the present embodiment, the motor 364_4 provided on the separable mobile side can be either a direct current motor or an alternating current motor, and should be understood as a torque generator.

The position signal S17 of the motor 364_4 is converted to an optical pulse or an electromagnetic pulse and fed back to the static side by noncontacting transfer by way of the coupler 363_2. The position amplifier 361_3 of the static unit side servocontroller 361 generates a speed command S_V from a position signal S17 and a position command S11 received from an upstream apparatus. Speed amplifier 361_5 generates a torque command S13 from a speed signal S12 and speed command S_V. Speed signal S12 also controls the output of high-frequency power generator 361_2. Torque command S13 is transmitted to the autonomous motor unit by noncontacting transfer by the coupler 363_1.

The transmission of power for driving the motor 364_4 is performed through high-frequency electromagnetic induction using the split-type high-frequency transformer 362. The output of the direct current power source 361_1 is converted to high-frequency rectangular waves by high-frequency power generator 361_2, supplied to the primary coil of the split-type high-frequency transformer 362, and the secondary output of the split-type high-frequency transformer 362 is supplied to the autonomous motor unit 364. This high-frequency power is rectified by the rectification circuit 364_1 provided in the autonomous motor unit 364 and made up of a filter and bridged diode, following which it is supplied to voltage stabilizing converter 364_2 and power switch 364_3, and makes motor driving power after passing through power switch 364_3. The voltage stabilizing converter 364_2 stabilizes the supply voltage from the rectification circuit 364_1, following which the power is supplied to the current amplifier 364_6 as power source S16.

The information is transferred as pulses as described above in order that data will not vary due to variations in the gap of the high-frequency electromagnetic induction coupler, since the optical coupler or high-frequency electromagnetic induction communication coupler is integrated with the split-type high-frequency transformer 362 for power transmission as couplers 363_1, 363_2, and torque command S13 is transmitted through coupler 363_2 after being converted to pulses by an analog-digital converter (not shown) by V-F conversion or PWM modulation.

In the autonomous motor unit 364, this command pulse is converted to an analog torque command S13 by a digital-analog converter (not shown). The current command generator 364_7 produces a current command S14 from the torque command S13 and a phase signal S15 of the motor 364_4 supplied from the sensor 364_5, and outputs the current command S14 to the current amplifier 364_6. If the motor is a direct current motor, the torque command S13 is used as current command S14 as is, and thus current command generator 364_7 is unnecessary.

The proportional or proportional -plus-integral control current amplifier 364_6 that controls the power supply for the motor 364_4 performs amplification depending on the difference between current command S14 and the detected current value, performs PWM modulation, and outputs to the power switch 364_3. This output serves as an input signal for the preceding-stage amplifier for base (or gate) drive of the power switch 364_3 made up of a power transistor, MOSFET, or IGBT. The power switch 364_3 converts the direct current main power supply fed from the above-described rectification circuit 364_1 in response to the base drive signal fed from current amplifier 364_6 and supplies PWM voltage to the motor 364_4 such that the torque command S13 and the torque feedback (current feedback) coincide.

The embodiment as described above meets the trend during recent years towards miniaturization of power switches and integration with peripheral circuits, and provides a method of control in which only the part (current control circuit) of the control unit that is peculiar to a motor type and a power switch are mounted on a portion (for example, a pallet or a rotating body) that is removable separately together with the motor and these are treated together as a single unit that generates torque, and the servocontroller on the static side effects control independent of the motor type. As a result, of the controls necessary for controlling a motor such as position control, speed control, and current control, those components that perform control universal and unaffected by motor type, i.e., the position loop for position control and the speed loop for speed control, are separated from those components that are peculiar to a motor type, i.e., the current loop for current control. As a result, the position and speed controllers and the power source control circuit are provided in the static side servocontroller (static unit side servocontroller), and in the autonomous motor unit, only the current loop peculiar to the mounted motor and the power switch are provided. In this way, control of a motor mounted on a removable element such as the above-mentioned pallet and rotating bodies is enabled, and in addition, the physical size of separately removable parts can be reduced. Furthermore, as shown in Fig. 31, autonomous motor units 370_1-370_3, on which are mounted direct current motor 371, induction motor 372 and synchronous motor 373, respectively, can be separately driven by a single static side servocontroller 361.

Fig. 32A and 32B are each perspective views showing concrete constructions of the split-type high-frequency transformer 362 of Fig. 31, and Fig. 33 is a view illustrating the high-frequency excitation performed in the present embodiment.

The power that drives the motor 364_4 is converted to a high-frequency form by transistor switches 391 which make up the high-frequency power generator 361_2 within the static side servocontroller 361, passes through split-type transformer 362 and is transferred to the autonomous motor unit 364 through high-frequency electromagnetic induction. In the device shown in Fig. 32A, voltage transformation is performed according to the turn ratio of coils 381_1, 381_2 wound onto E-shaped cores 382_1, 382_2, respectively. In the device shown in Fig. 37B, the transformation occurs according to the turns ratio of the coils 383_1, 383_2 wound onto pot-cores 384_1, 384_2.

High-frequency power is rectified by rectification circuit 364_1 within autonomous motor unit 364, and is converted to motor driving power after passing through power switch 364_3. The primary side of split-type high-frequency transformer 362 undergoes high-frequency excitation by a rectangular wave (or sine wave) inverter within static side servocontroller 361. As a result, the rectangular wave (or sine wave) voltage occurs on the secondary side according to the turn ratio of the primary and secondary coils, and undergoes full-wave rectication by the rectification circuit 364_1 made up of a high-frequency diode bridge 392 and an LC filter that is in turn made up of a reactor L and a smoothing capacitor C, the voltage thereby serving as a direct-current main power supply for motor drive. Further, the control voltage supply S16 for the communication and control circuits of the autonomous motor unit 364 is obtained through voltage stabilization by the voltage stabilizing converter 364_2 that is a voltage regulator within the autonomous motor unit 364.

Particularly, when the power source on the power-receiving side must be stabilized, a detected voltage is fed back without direct contact in the same way as the above-mentioned position data. Based on this voltage feedback and speed feedback information, stabilization is performed by effecting control through amplitude modulation or pulse width modulation in the static side servocontroller 361.

In this way, motor control system that is both separate-typed and characterized by superior torque controllability can be realized. This system can be adapted for motor control by way of a. rotating body as well as for separate-type control. However, in the former case, because power supply and signal transmission must both be performed coaxially with the rotation axis, some modifications are necessary. Power supply can be performed by using a pot-core-type split-core transformer shown in Fig. 37B. Signal transfer must be performed by an optical pulse communication system or a high-frequency electromagnetic induction communication system arranged coaxially with the pot-core of the split-core transformer.

As shown in Fig. 34, signal transfer by optical pulse can be performed through a hollow rotating shaft using a plurality of optical couplers having various light-emitting and light-sensing wavelength characteristics.

Within the interior of rotating shaft 402 rotatably secured by ball bearings 403_1, 403_2 in a static base, optical elements 404_1-404_4 and 405_1-405_4, which are light-emitting elements or light-receiving elements, are provided in an opposing relationship to form optical couplers. The optical elements 404_1-404_4 and 405_1-405_4 that make up optical couplers are selected so that the peaks of light-emitting wavelengths and light-receiving wavelengths of the optical couplers differ from those of each other optical couplers so as to prevent interference of the transmission signals.

As shown in Fig. 35A, in another example using optical pulses, light-emitting and light-receiving elements are coaxially arranged with shielding to prevent influence. In this case, the light-emitting wavelengths and light-receiving wavelengths for the plurality of optical couplers can be the same.

Fig. 35A shows the composition of the rotating unit side, in which light-guiding members 412_1-412_3 are formed in cylindrical shape coaxial with the rotation axis 411 having radii different from each other member, and the outer circumference of each of the light-guiding members 412_1-412_3 is covered with a light-shielding member. In the static side shown in Fig. 35B, light-guiding members 414_1-414_3 constituting optical couplers are embeded in light-shielding materials 416_1-416_3 formed in the same shape as light-guiding members 412_1-412_3 around the circumference of the bearing 415. Light beams that passes through the light-guiding members that make up one component of the optical coupler propagates to the opposing light-guiding members provided in the other component without influencing each other beam by virtue of light-shielding members 413_1-413_3 and light-shielding material 416_1-416_3.

Signal transfer by optical pulses is effected by means of these light-guiding members, and light-guiding members can be constructed with light-emitting element and light receiving elements.

Signal transfer by high frequency electromagnetic induction is preferably used in a case in which a worsening ambience deteriorates the reliability of optical pulse communication, and in the same way as the optical pulse transmission method shown in Fig. 34 and Fig. 35, either a method in which the split cores are arranged coaxially in a radial direction or a method in which they are arranged in the axial direction is possible.

It is possible that each of the above-described split-core high-frequency transformers and each coupler are formed as an integrated unit, and control of an autonomous motor unit by way of a rotating body can be easily realized by arranging on the same shaft the coupler shown in Fig. 35A and 35B and the split-core high-frequency transformers of pot-core configuration 384_1, 384_2 shown in Fig. 32B.

Fig. 36 is a block diagram showing a noncontacting power transmission system according to an other embodiment of the present invention.

In the present embodiment, power supply as well as torque control is performed both for a first autonomous motor unit 422 and a second autonomous motor unit 423 by a single static side servocontroller 421. Because the control circuit of the servocontroller 421 on the static side and the constitution of the first autonomous motor unit 422 and the second autonomous motor unit 423 are the same as are shown in Fig. 30, only the principal parts and operation will be here explained.

The high-frequency power to be supplied from the static side servocontroller 421 is sent to the first autonomous motor unit 422 by way of a first split-core high-frequency transformer 424, and to the second autonomous motor unit 423 by way of a second split-core high-frequency transformer 425. To perform control, couplers 426_1-426_4 are provided between the static side servocontroller 421 and the first autonomous motor unit 422, and couplers 427_1-427_2 are provided between the first autonomous motor unit 422 and the second autonomous motor unit 423. Transmission and reception of torque commands and feedback information for the first autonomous motor unit 422 is carried out by couplers 426_1, 426_2, and for the second autonomous motor unit 423, transmission and reception of torque commands and feedback information is carried out by couplers 426_3, 426_4, 427_1, 427_2.

As described above, because power supply and torque control for an autonomous motor unit are effected by way of another autonomous motor unit in this embodiment, the transmission system enables effective driving and removing a device such as a multi-articulated robot in which the autonomous motor units are combined serially in multiple stages. Similarly it is also possible that an autonomous motor unit drives a movable member coupled to the autonomous motor unit.

Furthermore, in autonomous motor units not intercombined in multiple stages and provided in paralle, it is of course possible to perform contorl not by way of an autonomous motor unit but directly by the static side servocontroller.

The novel separate-type motor control method according to the present invention as shown in each of the above-explained embodiments enables realizing decentralization of autonomous units through the motor drivability of functional elements represented by processing machine ATC tools, and robot end effectors; and positioning and jig automatizations on pallets which could not be achieved with a high degree of reliability with a mechanical framework or electrical framework of connection and disconnection of connectors with electrodes, thereby enabling comprehensive automatization of a control system.

Control in the form of controlling a motor on a rotating body that performs multiple rotations (for example, the motorization of a lathe head chucking member or linear drive by motor on a tool post installed at the shaft end of a machine tool) is also possible.

Furthermore, as described above, by appropriately dividing the controller into a static side and a motor side (machine-mounted side), the physical size of a separately removable part can be reduced, and any autonomous functional unit with a direct current motor, induction motor, or synchronous motor can be remotely driven by a single static side servocontroller.

The apparatus according to the above embodiments (Fig. 30,36) transfer power by means of high-frequency electromagnetic induction using a split-core transformer and perform transmission of torque commands in the form of optical transmission or high-frequency electromagnetic induction transmission, and consequently can stand up to severe conditions such as subjection to water or oil, do not give rise to sparks or electrode damage, and feature the capability to be physically split or separated on hot lines. This is a device that can meet the recently growing demand for autonomous machine elements with mounted motors or for motor control on a rotating body.

The present invention also provides a power source controller having wide interchangeability, because direct current motors, induction motors, and synchronous motors can be treated collectively as torque generators regardless of motor type.

By using these embodiments, the above-described effects can be attained in the following specific cases to effect unprecedented improvements and a technological breakthrough in the field.

1) Motor control of position indexing for a workpiece on a pallet.
2) Wireless drive for power and signals for each axis of motor actuators of a multiarticulated robot.
3) Wireless tool drive in an automatic tool exchange of a machine tool (machining center).
4) Control of motor actuators attached to the main shaft tip of a machine tool involving multiple rotation (for example, motorization of a chucking member at a lathe head or a tool post on a main shaft).
5) Control particularly when torque controllability is required for the motor, and moreover, when the pallet on which the motor is mounted must itself be able to move autonomously, for example, control when the motor is used for centering and clamping of a workpiece on a work pallet.
6) Control-signal transmission and power supply to various electric loads including motors in chambers isolated by transparent material such as glass or by nonmagnetic metals, such as in a cleanroom.
7) Control signal transmission and power supply to various electric loads including motors under conditions such as a vacuum or underwater, in which power supply through eelctrode contact is impossible.

In particular, of the above applications, in uses in which a motor is employed as a torque generator such as in chucking or centering and clamping the present

invention can be effectively used without alteration, because all motors are understood in the present invention to be essentially torque generators and the separate-type control is exercised.

Because the above embodiments (Fig. 35,36) are constructed as explained above, they exhibit the following effects:

The embodiments have the effect of enabling miniaturization of an autonomous motor unit that is removable, increasing the capacity to realize remotely controlled motors, as well as of increasing the range of use. The present invention has the further effect that, because the construction of the static side servocontroller that controls an autonomous motor unit is unaffected by the motor type, the same static side servocontroller can be used for any type of motor, and the types of the static side servocontrollers can be minimized, thereby enabling more efficient construction. The present invention also has the effect that the separately controlled motors can stand up to severe conditions such as subjection to water or oil, do not give rise to sparks or electrode damage, and feature the capability of being physically separated and not connected on hot lines.

Furthermore, the present invention, by taking advantage of the fact that the state of electromagnetic induction coupling between the coils is virtually unaffected by a degree of variation in the relative positions of the static unit and movable unit during power supply, provides the effect of allowing a stable power supply in uses in which power supply by conventional wiring cannot be used due to fatigue caused by the rapid short-stroke movement of the movable body in one-dimensional, two-dimensional, or three dimensional directions.

Claims

1. A noncontacting power transfer apparatus for a machine apparatus wherein power is supplied without direct electric contact from a static unit to a rotatable unit of the machine apparatus, characterized by:

   a split-core made up of a first core (51) and a second core (53) secured to the static unit and the rotatable unit, respectively, that form a magnetic circuit the magnetic path length of which does not vary by an arbitrary rotation of the second core (53) with respect to the first core (51); a first coil (54) connected to a high-frequency alternating power source provided in the static unit for providing magnetomotive force to the magnetic circuit; and a second coil (55) connected to a power-receiving device secured to the rotatable unit, said second coil (55) being arranged to link with magnetic flux that passes through the magnetic circuit.

2. The apparatus according to claim 1 wherein one (51) of the first core and second core is a high-frequency magnetic member having a U-shaped cross section in which two parallel extending leg parts (71) is directed perpendicular to the axis of the rotation of the rotatable unit, and the other core (53) is a high-frequency magnetic member of cylindrical shape arranged such that its central axis is coaxial with the axis of rotation, each end portion of the cylindrical core being received by a receiving hole (52) provided in each of the leg parts of the U-shaped core, the two cores being slidably rotatable relative to each other around said axis.

3. The apparatus of claim 2 wherein the fitting surfaces of said U-shaped core and said cylindrical core are taper formed, and wherein each leg part (71) of the U-shaped core has a slot (74) extending from the end of the leg part to the receiving hole (72) for attaching and removing the cylindrical core (73) to and from the receiving hole (72).

4. The apparatus according to claim 3 wherein the first core is a cylindrical core (63), the second core is a U-shaped core (61), the second core (61) is loosely secured to the rotatable unit such that the second core (61), when magnetically excited, can fit closely against the first core (63), the first coil is wound on the first core, and the second coil (65) is wound radially spaced from and covering the first coil.

5. The apparatus according to claim 3 wherein the first core (51) is a U-shaped core, the second core (53) is cylindrical core, and the first and second coils (54, 55) are wound on the first and second cores, respectively.

6. The noncontacting power transfer apparatus according to claim 5 for supplying power to a pallet on which is mounted a servo motor axis of a machine tool to be added, wherein the first core (91) is fixed to a static unit adjacent to the axis of rotation of a rotating table (82) on which the pallet (83) is mounted, and the second core (93) is fixed to the pallet (83) coaxial with the axis of rotation of the pallet (83).

7. A non-contacting rotary transformer for transfer of power or transmission of signals between first and second members arranged for relative rotary movement, comprising a first coil (54; 65; 104) carried by a first (51; 63; 101) of said members and a second coil (55; –; 105) carried by a second (53; 63; 103) of said members, and comprising core means (51, 53; 61, 63; 101; 101, 111) forming part of a magnetic path extending through the first and second coils and being not influenced by the angular relative position of said two members, the first of said two members being made from high-frequency magnet-

ic material and forming part of said core means and having legs being perpendicular to the axis of rotation of said second member and the second of said two members being of cylindrical shape, characterized in that said first member (51; 61; 101) is of U-shaped geometry and in that the two parallel extending legs of said member freely grip over a portion (93; 102) of said second member such that joining of said two members may be obtained by relative linear movement thereof in a direction being perpendicular to the axis of relative rotary movement.

8. The rotary transformer in accordance with claim 7, characterized in that the two parallel legs (71) of said first member (51; 61) are each provided with a laterally open slot (74) receiving an end portion of said second member (53; 63) and in that the second member (53; 63) is also made from high-frequency magnetic material.

9. The rotary transformer in accordance with claim 8, characterized in that the opposing surfaces of the slots (74) of the legs (71) of the U-shaped first member (51; 61) and of the cylindrical second member (53; 63) are tapered and conical, respectively.

10. The rotary transformer in accordance with claim 9, characterized in that the U-shaped first member (61) and the cylindrical second member (61) are loosely interconnected such that upon magnetical excitation the two members can closely fit, the first coil (54; –) and the second coil (55; 65) being wound such that they are radially spaced but cover the same axial region.

11. The rotary transformer as in one of claims 8 - 10, characterized in that the second coil (--) is arranged on said cylindrical second member (63), while the first coil (65) is mould-formed so as to slidingly fit onto the surface of said second member (63).

12. The rotary transformer in accordance with claim 7, characterized in that the two legs of said core forming U-shaped first member (101) grip over a peripheral portion (303) or a radially projecting flange portion (102) of said second member (103; 290), and in that the second coil (105; 294) is arranged in said peripheral or radial flange portion.

13. The rotary transformer in accordance with claim 12, characterized in that the second coil (105) is carried by a non magnetic portion (102) of said second member (103).

14. The rotary transformer in accordance with claim 12, characterized in that the second coil (105) is carried by a portion (111) of said cylindrical member made from high-frequency magnetic material.

15. Use of the noncontacting rotary transformer according to claim 7 in a machine apparatus.

16. Use in a machine apparatus according to claim 15 wherein the machine apparatus is made up of a static unit and a rotatable unit capable of rotation and removal, the rotatable unit having an autonomous motor unit; wherein

the autonomous motor unit is provided with at least: a motor; the components secured to the rotatable unit of the power transfer apparatus that receives power for driving the motor without direct electric contact; drive means that inputs the power supplied through the power transfer apparatus and drive the motor; a current control unit for driving the drive means that is separated from a servocontroller for controlling rotation of the motor; the components of a first signal transfer apparatus fixed to the rotatable unit for receiving without direct electric contact torque commands to be supplied to the current control unit; detecting means for detecting operation information of the motor; the components of the second signal transfer apparatus fixed to the rotatable unit for transmitting output signals of the detecting means without direct electric contact;
and the static unit comprising at least: a high-frequency power source; components of the power transfer apparatus secured to the static unit for transmitting power of the high-frequency power source to the autonomous motor unit without direct electric contact; components of the second signal transfer apparatus fixed to the rotatable unit for receiving the output of the detecting means of the autonomous motor unit without direct electric contact; a static unit side servocontroller, made up of a portion of the servocontroller from which the current control unit is separated, for generating torque commands from both a command signal supplied from an upstream apparatus and received output of the detecting means; and the componenets of the first signal transfer apparatus fixed to the static unit for transmitting torque commands outputted from the static unit side servocontroller to the autonomous motor unit without direct electric contact.

17. Use in a machine apparatus according to claim 16 wherein a speed amplifier and a position amplifier are provided in the static unit side servocontroller for generating a torque command to control the motor from the position and speed of the motor indicated by the content of detection effected by the de-

tecting means, and a current amplifier is provided in the autonomous motor unit for controlling the motor in response to the torque command.

18. Use in a machine apparatus according to claim 16 wherein a speed amplifier and a position amplifier are provided in the static unit side servocontroller for generating a torque command from the position and speed of the motor indicated by the content of detection effected by the detecting means and from a command signal from an upstream apparatus; and

in the current control unit are provided a current amplifier for controlling the motor in response to the current command, and a current command generator for generating a current command both from the torque command and from the phase of the motor indicated by the content of detection effected by the detecting means.

19. Use in a machine apparatus according to claim 15 wherein are provided a plurality of autonomous motor units combined in multiple stages that receive torque commands from a static unit side servocontroller, the power supply from the static unit to each stage of the autonomous motor units, and communication of data signals and control signals between the static unit side servocontroller and the current control unit of each stage are performed through a power transfer apparatus and signal transfer apparatus provided between the static unit and the first stage of the autonomous motor units and between the autonomous motor units in individual stages.

20. Use in a machine apparatus according to one of claims 17 to claim 19 wherein the power transfer apparatus and the signal transfer apparatus are constructed in one integrated unit.

21. Use in a machine apparatus according to claim 16 wherein the autonomous motor unit controllably drives a movable member installed in that autonomous motor unit or controllably drives the mechanism of that autonomous motor unit itself.

22. Use in a machine apparatus according to claim 16 wherein the machine apparatus is a machine tool, a robot device, or attachments thereto.

23. Use in a machine apparatus according to claim 21, wherein the autonomous motor unit is constructed as a unit capable of removal from the machine apparatus.

24. Use in a machine apparatus according to claim 15, wherein the machine apparatus includes a rotary apparatus, and the power transfer apparatus and the signal transfer apparatus are established coaxially with the axis of rotation of the rotary apparatus.

25. Use in an apparatus according to claim 24, wherein the rotary apparatus has an electric load installed at the end of its rotation shaft, and wiring from the second coil of the power transfer apparatus to the end of the rotation shaft, and the wiring from the component fixed to the rotatable unit of the signal transfer apparatus to the end of the rotation shaft are arranged in a groove provided on the outer circumference of the rotation shaft in the direction of the shaft axis or within a hollow portion of a hollow rotation shaft.

26. Use in an apparatus according to claim 25, wherein the rotaty apparatus is a motor; the second core of the power transfer apparatus is provided on the rotation shaft supported by bearings at both ends; the first core is provided secured to the static unit and confronting the second core across a gap; and the signal transfer apparatus is provided on the outer periphery of the rotation shaft and at an opposing position of the static unit.

27. Use in an apparatus according to claim 25, wherein the rotary apparatus is a reduction arrangement, the second core of the power transfer apparatus is provided on the output shaft of the variable speed supported by bearings at both ends; the first core is provided secured to the static unit and confronting the second core across a gap; and the signal transfer apparatus according to claim 12 is provided on the outer periphery of the output shaft of the variable speed and at an opposing position of the static unit.

28. A method of controlling noncontacting power supply for a motor applicable to the machine apparatus as described in claim 16 wherein

the static unit side servocontroller generates a torque command from both a command signal supplied from a prescribed upstream apparatus and the content of detection effected by the detecting means, and provides the torque command to an autonomous motor unit, and
the autonomous motor unit drives a motor in response to the torque command provided from the static unit side servocontroller.

29. A method of controlling noncontacting power supply according to claim 28 wherein

the static unit side servocontroller generates a torque command from both a command signal supplied from an upstream apparatus and a speed and a position of the motor indicated by the content of detection effected by the detecting means and provides the torque command

to an autonomous motor unit, and the autonomous motor unit drives a motor using the torque command provided from the servocontroller on the static unit side as a current command.

30. A method of controlling noncontacting power supply for a motor according to claim 28 wherein

the servocontroller on the static unit side generates a torque command from both a command signal inputted from an upstream apparatus and a speed and a position of the motor indicated by the content of detection effected by detecting means and provides the torque command to an autonomous motor unit, and the autonomous motor unit generates a current command both from a phase of the motor indicated by the content of detection effected by the detection means and from the torque command provided from the servocontroller on the static unit side, and drives a motor.

Patentansprüche

1. Kontaktlose Leistungsübertragungsvorrichtung für eine Maschineneinrichtung, wobei Leistung ohne direkten elektrischen Kontakt von einer statischen Einheit auf eine drehbare Einheit der Maschineneinrichtung übertragen wird, gekennzeichnet durch einen gespaltenen Kern, der aus einem ersten Kern (51) und einem zweiten Kern (53) besteht, die an der statischen Einheit bzw. der drehbaren Einheit befestigt sind und eine magnetische Schaltung bilden, deren magnetische Weglänge sich durch eine beliebige Rotation des zweiten Kerns (53) in bezug auf den ersten Kern (51) nicht verändert, eine erste Spule (54), die mit einer Hochfrequenz-Wechselstromquelle verbunden ist, und in der statischen Einheit vorgesehen ist, um die magnetische Schaltung mit einer magnetomotorischen Kraft zu versehen, und eine zweite Spule (55), die mit einer Leistung empfangenden Vorrichtung verbunden ist und die an der drehbaren Einheit befestigt ist, wobei die zweite Spule (55) derart angeordnet ist, daß sie mit einem magnetischen Fluß, der durch die magnetische Schaltung tritt, in Verbindung steht.

2. Vorrichtung nach Anspruch 1, wobei ein Kern (51) von dem ersten Kern und dem zweiten Kern ein Hochfrequenzmagnetelement ist, das einen U-förmigen Querschnitt hat, in dem die beiden sich parallel erstreckenden Armteile (71) senkrecht zur Rotationsachse der drehbaren Einheit ausgerichtet sind, und der andere Kern (53) ein Hochfiequenzmagnetelement mit zylindrischer Form ist, das derart angeordnet ist, daß seine zentrale Achse koaxial zur Rotationsachse steht, wobei jeder Endbereich des zylindrischen Kerns von einem Aufnahmeloch (52) aufgenommen wird, das in jedem Armteil des U-förmigen Kerns vorgesehen ist, wobei die beiden Kerne um besagte Achse in bezug aufeinander gleitend drehbar sind.

3. Vorrichtung nach Anspruch 2, wobei die aufeinander passenden Flächen des U-förmigen Kerns und des zylindrischen Kerns sich verjüngend ausgebildet sind und wobei jedes Armteil (71) des U-förmigen Kerns einen Schlitz (74) aufweist, der sich vom Ende des Armteils zu dem Aufnahmeloch (72) erstreckt, um den zylindrischen Kern (73) in dem Aufnahmeloch (72) anzubringen und aus diesem zu entfernen.

4. Vorrichtung nach Anspruch 3, wobei der erste Kern ein zylindrischer Kern (63) ist, der zweite Kern ein U-förmiger Kern (61), der zweite Kern (61) lose an der drehbaren Einheit befestigt ist, derart, daß der zweite Kern (61), wenn er magnetisch angeregt wird, sich eng an den ersten Kern (63) anlegen kann, die erste Spule auf den ersten Kern gewickelt ist und die zweite Spule (65) in radialem Abstand zu der ersten Spule gewickelt ist und diese abdeckt.

5. Vorrichtung nach Anspruch 3, wobei der erste Kern (51) ein U-förmiger Kern ist, der zweite Kern (53) ein zylindrischer Kern ist, und die erste und die zweite Spule (54,55) auf den ersten bzw. den zweiten Kern gewickelt sind.

6. Kontaktlose Leistungsübertragungsvorrichtung nach Anspruch 5 zur Übertragung von Leistung auf eine Palette, auf die eine Achse des Servomotors eines Maschinenwerkzeugs, das hinzugefügt werden kann, montiert ist, wobei der erste Kern (91) an einer statischen Einheit befestigt ist, die neben der Rotationsachse eines rotierenden Tisches (82) angeordnet ist, auf den die Palette (83) montiert ist, und der zweite Kern (93) koaxial zur Rotationsachse der Palette (83) an der Palette (83) befestigt ist.

7. Kontaktloser Dynamotor zur Übertragung von Leistung oder Übermittlung von Signalen zwischen einem ersten und einem zweiten Element, die so angeordnet sind, daß sie eine relative Rotationsbewegung ausführen können, aufweisend eine erste Spule (54;65;104), die von einem ersten (51;63; 101) besagter Elemente getragen wird, und eine zweite Spule (55;--;105), die von einem zweiten (53;63;103) besagter Elemente gehalten wird, und Kerneinrichtungen (51,53;61,63;101 ;101,111) aufweisend, die einen Teil des magnetischen Wegs bilden, der sich durch die erste und die zweite Spule erstreckt und nicht durch die relative, einen Winkel bildende Position der beiden Elemente zueinander

beeinflußt wird, wobei das erste beider Elemente aus einem hochfrequenten magnetischen Material gefertigt ist, und einen Teil der Kerneinrichtung bildet und Arme aufweist, die senkrecht zur Rotationsachse des zweiten Elements stehen und wobei das zweite der beiden Elemente eine zylindrische Form hat, dadurch gekennzeichnet, daß das erste Element (51;61;101) eine U-förmige Geometrie aufweist und die beiden sich parallel erstreckenden Arme dieses Elements frei über einen Bereich (93; 102)des zweiten Elements greifen, derart, daß eine Verbindung der beiden Elemente erhalten werden kann, indem sie relativ zu einander linear in eine Richtung bewegt werden, die senkrecht zur Achse der relativen Rotationsbewegung steht.

8. Dynamotor nach Anspruch 7, dadurch gekennzeichnet, daß die beiden parallelen Arme (71) des ersten Elements (51;61) jeweils mit einem zu einer Seite hin offenen Schlitz (74) versehen sind, der einen Endbereich des zweiten Elements (53;63) aufnimmt, und das zweite Element (53;63) ebenfalls aus hochfrequentem magnetischen Material besteht.

9. Dynamotor nach Anspruch 8, dadurch gekennzeichnet, daß die sich gegenüberliegenden Flächen der Schlitze (74) der Arme (71) des U-förmigen ersten Elements (51;61) und des zylindrischen zweiten Elements (53; 63) sich verjüngen bzw. konisch sind.

10. Dynamotor nach Anspruch 9, dadurch gekennzeichnet, daß das U-förmige erste Element (61) und das zylindrische zweite Element (61) lose miteinander verbunden sind derart, daß sich beide Elemente durch eine magnetische Anregung eng aneinanderlegen können, wobei die erste Spule (54;–) und die zweite Spule (55;65) derart gewikkelt sind, daß sie radial voneinander beabstandet sind, jedoch denselben axialen Bereich abdecken.

11. Dynamotor nach einem der Ansprüche 8-10, dadurch gekennzeichnet, daß die zweite Spule (–) auf dem zylindrischen zweiten Element (63) angeordnet ist, wohingegen die erste Spule (65) in Form hergestellt ist, so daß sie gleitend auf die Oberfläche des zweiten Elements (63) paßt.

12. Dynamotor nach Anspruch 7, dadurch gekennzeichnet, daß die beiden Arme des Kern bildenden U-förmigen ersten Elements (101) über einen Umfangsbereich (303) oder einen radial vorstehenden Flanschbereich (102) des zweiten Elements (103; 290) greifen und daß die zweite Spule (105;294) in dem Umfangsbereich oder radialen Flanschbereich angeordnet ist.

13. Dynamotor nach Anspruch 12, dadurch gekennzeichnet, daß die zweite Spule (105) von einem nicht magnetischen Bereich (102) des zweiten Elements (103) getragen wird.

14. Dynamotor nach Anspruch 12, dadurch gekennzeichnet, daß die zweite Spule (105) von einem Bereich (111) des zylindrischen Elements getragen wird, das aus hochfrequentem magnetischen Material gefertigt ist.

15. Verwendung des kontaktlosen Dynamotor nach Anspruch 7 in einer Maschineneinrichtung.

16. Verwendung in einer Maschineneinrichtung nach Anspruch 15, wobei die Maschineneinrichtung aus einer statischen Einheit und einer drehbaren Einheit besteht, die geeignet ist, sich zu drehen und entfernt zu werden, wobei die drehbare Einheit eine autonome Motoreinheit aufweist, wobei die autonome Motoreinheit mit zumindest:

einem Motor, den Komponenten, die an die drehbare Einheit der Leistungsübertragungsvorrichtung befestigt sind, die Leistung für den Motorantrieb ohne direkten elektrischen Kontakt empfängt, Antriebseinrichtungen, die die Leistung, die über die Leistungsübertragungsvorrichtung zugeführt wird, liefert und den Motor antreibt, eine Stromsteuereinheit, um die Antriebseinrichtung anzutreiben, die von der Servosteuerung zur Steuerung der Rotation des Motors getrennt ist, die Komponenten einer ersten Signalübertragungsvorrichtung, die an der drehbaren Einheit befestigt sind, um ohne direkten elektrischen Kontakt Drehmomentbefehle zu empfangen, die der Stromsteuereinheit zugeführt werden, Detektionseinrichtungen, um Informationen über den Betrieb des Motors zu erfassen, die Komponenten der zweiten Signalübertragungseinrichtung, die an der drehbaren Einheit zur Übertragung von Ausgabesignalen der Detektionseinrichtungen ohne direkten elektrischen Kontakt befestigt sind,

versehen ist,
und wobei die statische Einheit zumindest:

eine hochfrequente Stromquelle, Komponenten der Leistungsübertragungsvorrichtung, die an der statischen Einheit zur Übertragung von Leistung von der hochfrequenten Stromquelle auf die autonome Motoreinheit ohne direkten elektrischen Kontakt befestigt sind, Komponenten der zweiten Signalübertragungseinrichtung, die an der drehbaren Einheit befestigt sind, um das Ausgabesignal der Detektionsein-

richtung der autonomen Motoreinheit ohne direkten elektrischen Kontakt zu empfangen, eine Servosteuerung an der Seite der statischen Einheit, die aus einem Teil der Servosteuerung besteht, von der die Stromsteuereinheit abgetrennt ist, um Drehmomentbefehle sowohl aus einem Befehlssignal, das von einer stromaufwärts angeordneten Einrichtung, als auch aus einem empfangenen Ausgabesignal der Detektionseinrichtung erzeugt, und die Komponenten des ersten Signalübertragungseinrichtung, die an der statischen Einheit zur Übertragung von Drehmomentbefehlen befestigt sind, die von der Servosteuerung an der Seite der statischen Einheit an die autonome Motoreinheit ohne direkten elektrischen Kontakt ausgegeben werden,

aufweist.

17. Verwendung in einer Maschineneinrichtung nach Anspruch 16, wobei ein Geschwindigkeitsverstärker und ein Positionsverstärker in der Servosteuerung an der Seite der statischen Einheit vorgesehen sind, um einen Drehmomentbefehl zur Steuerung des Motors aus der Position und Geschwindigkeit des Motors zu erzeugen, die durch den Inhalt der Erfassung angegeben werden, die durch die Detektionseinrichtung erfolgt, und einen Stromverstärker in der autonomen Motoreinheit vorgesehen ist, um den Motor als Antwort auf das Drehmomentsignal zu steuern.

18. Verwendung in einer Maschineneinrichtung nach Anspruch 16, wobei ein Geschwindigkeitsverstärker und ein Positionsverstärker in der Servosteuerung an der Seite der statischen Einheit vorgesehen sind, um einen Drehmomentbefehl zur Steuerung des Motors aus der Position und Geschwindigkeit des Motors zu erzeugen, die durch den Inhalt der Erfassung angegeben werden, die durch die Detektionseinrichtung erfolgt, und
in der Stromsteuereinheit ein Stromverstärker zur Steuerung des Motors in Antwort auf den Strombefehl und ein Erzeuger für Strombefehle vorgesehen sind, um einen Strombefehl sowohl aus dem Drehmomentbefehl als auch aus der Phase des Motors zu erzeugen, die durch den Inhalt der Erfassung, die durch die Detektionseinrichtungen erfolgt, angegeben werden.

19. Verwendung in einer Maschineneinrichtung nach Anspruch 15, wobei mehrere autonome Motoreinheiten vorgesehen sind, die in mehreren Stufen kombiniert sind, die Drehmomentbefehle von einer Servosteuerung auf der Seite der statischen Einheit empfangen, die Leistungszuführung von der statischen Einheit in jede Stufe der autonomen Motoreinheiten und Übertragung von Datensignalen und Steuersignalen zwischen der seitlichen Servosteuerung auf der Seite der statischen Einheit und der Stromsteuereinheit in jeder Stufe über eine Leistungsübertragungsvorrichtung erfolgen, die zwischen der statischen Einheit und der ersten Stufe der autonomen Motoreinheiten in den einzelnen Stufen vorgesehen sind.

20. Verwendung einer Maschineneinrichtung nach einem der Ansprüche 17 bis 19, wobei die Leistungsübertragungsvorrichtung und die Signalübertragungseinrichtung in einer integrierten Einheit aufgebaut sind.

21. Verwendung einer Maschineneinrichtung nach Anspruch 16, wobei die autonome Motoreinheit steuerbar ein bewegliches Element antreibt, das in die besagte Motoreinheit eingebaut ist oder steuerbar den Mechanismus der autonomen Motoreinheit selbst steuert.

22. Verwendung in einer Maschineneinrichtung nach Anspruch 16, wobei die Maschineneinrichtung ein Maschinenwerkzeug, eine Robotoreinrichtung oder Zusatzgeräte für diese ist.

23. Verwendung in einer Maschineneinrichtung nach Anspruch 21, wobei die autonome Motoreinheit als Einheit aufgebaut ist, die geeignet ist, aus der Maschineneinrichtung entfernt zu werden.

24. Verwendung in einer Maschineneinrichtung nach Anspruch 15, wobei die Maschineneinrichtung eine Dreheinrichtung beinhaltet und die Leistungsübertragungsvorrichtung und die Signalübertragungseinrichtung koaxial in bezug auf die Rotationsachse der Dreheinrichtung befestigt sind.

25. Verwendung in einer Einrichtung nach Anspruch 24, wobei die drehbare Einrichtung eine elektrische Ladung aufweist, die am Ende ihrer Rotationswelle installiert ist, und eine Verdrahtung von der zweiten Spule der Leistungsübertragungsvorrichtung zum Ende der Rotationswelle und die Verdrahtung, die am Ende der drehbaren Einheit des Signalübertragungseinrichtung am Ende der Rotationswelle in einer Vertiefung, die auf dem Außenumfang der Rotationswelle in Richtung der Wellenachse oder in einem Hohlbereich einer hohlen Rotationswelle vorgesehen ist, angeordnet sind.

26. Verwendung in einer Einrichtung nach Anspruch 25, wobei die drehbare Einrichtung ein Motor ist, der zweite Kern der Leistungsübertragungsvorrichtung auf der Rotationswelle vorgesehen ist und an beiden Ende durch Lager gehalten werden, wobei vorgesehen ist, daß der erste Kern an der stati-

schen Einheit befestigt ist und dem zweiten Kern über einen Zwischenraum gegenübersteht, und eine Signalübertragungseinrichtung am äußeren Umfangsrand der Rotationswelle und der statischen Einheit gegenüberstehend angeordnet, vorgesehen ist.

27. Verwendung in einer Einrichtung nach Anspruch 25, wobei die Rotationseinrichtung eine Reduktionsanordnung ist, der zweite Kern der Leistungsübertragungsvorrichtung auf der Ausgabewelle mit variabler Geschwindigkeit, die an beiden Enden durch Lager gehalten wird, vorgesehen ist, es vorgesehen ist, daß der erste Kern an der statischen Einheit befestigt ist und dem zweiten Kern über einen Zwischenraum gegenübersteht, und die Signalübertragungseinrichtung nach Anspruch 12 auf dem äußeren Umfang der Ausgabewelle von variabler Geschwindigkeit in einer der statischen Einheit gegenüberliegenden Position angeordnet ist.

28. Verfahren zur Steuerung einer kontaktlosen Leistungszuführung für einen Motor, der für die Maschineneinrichtung, wie sie in Anspruch 16 beschrieben ist, verwendbar ist, wobei

die Servosteuerung an der Seite der statischen Einheit einen Drehmomentbefehl sowohl aus einem Befehlssignal, das von einer vorher beschriebenen stromaufwärts angeordneten Einrichtung zugeführt wird, als auch aus dem Inhalt der Detektion, die durch die Detektionseinrichtungen erfolgt, erzeugt und den Drehmomentbefehl einer autonomen Motoreinheit zuführt,und
die autonome Motoreinheit einen Motor als Antwort auf das Drehmomentsignal, das von der Servosteuerung auf der Seite der statischen Einheit bereitgestellt wird, antreibt.

29. Verfahren zur Steuerung kontaktloser Stromzuführung nach Anspruch 28, wobei

die Servosteuerung an der Seite der statischen Einheit einen Drehmomentbefehl sowohl aus einem Befehlssignal, das von einer vorher beschriebenen stromaufwärts angeordneten Einrichtung zugeführt wird, als auch aus einer Geschwindigkeit und einer Position des Motors, die durch den Inhalt der Detektion angegeben werden, die durch die Detektionseinrichtungen erfolgt, erzeugt und den Drehmomentbefehl einer autonomen Motoreinheit zuführt, und
der autonome Motoreinheit einen Motor antreibt, wobei der Drehmomentbefehl, der von der Servosteuerung auf der Seite der statischen Einheit bereitgestellt wird, als Strombefehl verwendet wird.

30. Verfahren zur Steuerung kontaktloser Leistungszuführung für einen Motor nach Anspruch 28, wobei

die Servosteuerung an der Seite der statischen Einheit einen Drehmomentbefehl sowohl aus einem Befehlssignal, das von einer vorher beschriebenen stromaufwärts angeordneten Einrichtung geliefert wird, als auch aus einer Geschwindigkeit und einer Position des Motors, die durch den Inhalt der Detektion angegeben wird, die durch die Detektionseinrichtungen erfolgt, erzeugt und den Drehmomentbefehl einer autonomen Motoreinheit zuführt, und
die autonome Motoreinheit ein Stromsignal sowohl aus einer Phase des Motors, die durch den Inhalt der Detektion angegeben wird, die durch die Detektionseinrichtungen erfolgt, und aus dem Drehmomentbefehl, der von der Servosteuerung auf der Seite der statischen Einheit bereitgestellt wird, erzeugt und den Motor antreibt.

Revendications

1. Appareillage de transmission de puissance sans contact pour un appareil d'usinage, dans lequel la puissance est acheminée sans contact électrique direct à partir d'une unité statique jusqu'à une unité rotative de l'appareil d'usinage, caractérisé par:

un noyau fendu constitué par un premier noyau (51) et par un second noyau (53) fixés à l'unité statique et à l'unité rotative, respectivement, qui forment un circuit magnétique dont la longueur de chemin magnétique n'est pas soumise à des variations dues à une rotation arbitraire du second noyau (53) par rapport au premier noyau (51);
une première bobine (54) reliée à une source de courant alternatif de haute fréquence, prévue dans l'unité statique pour fournir une force magnétomotrice au circuit magnétique; et une seconde bobine (55) reliée à un dispositif récepteur de puissance fixé à l'unité rotative, ladite seconde bobine (55) étant arrangée pour établir une liaison avec le flux magnétique qui passe à travers le circuit magnétique.

2. Appareil selon la revendication 1, dans lequel le premier noyau (51) parmi les premier et second noyaux est un élément magnétique à haute fréquence possédant une section transversale en U, dans lequel deux parties (71) en forme de branches s'étendant en parallèle sont orientées perpendiculairement à l'axe de rotation de l'unité rotative, et l'autre noyau (53) est un élément magnétique à haute fréquence de forme cylindrique arrangé de

telle sorte que son axe central soit coaxial avec l'axe de rotation, chaque portion terminale du noyau cylindrique venant se loger dans un trou de réception (52) pratiqué dans chacune des parties en forme de branches du noyau en U, les deux noyaux étant à même de tourner en coulissement l'un par rapport à l'autre autour dudit axe.

3. Appareil selon la revendication 2, dans lequel les surfaces de jointement dudit noyau en forme de U et dudit noyau cylindrique sont de forme conique, et dans lequel chaque partie (71) en forme de branche du noyau en U possède une fente (74) s'étendant depuis l'extrémité de la partie en forme de branche jusqu'au trou de réception (72) pour fixer et retirer le noyau cylindrique (73) au et du trou de réception (72).

4. Appareil selon la revendication 3, dans lequel le premier noyau est un noyau cylindrique (63), le second noyau est un noyau en U (61), le second noyau (61) est fixé avec du jeu à l'unité rotative de telle sorte que le second noyau (61), lorsqu'il est excité par voie magnétique, peut venir se disposer en ajustage serré contre le premier noyau (63), la première bobine étant roulée sur le premier noyau et la seconde bobine (65) étant enroulée en étant espacée en direction radiale par rapport à la première bobine et en recouvrant cette dernière.

5. Appareil selon la revendication 3, dans lequel le premier noyau (51) est un noyau en U, le second noyau (53) est un noyau cylindrique et les première et seconde bobines (54, 55) sont enroulées sur les premier et second noyaux, respectivement.

6. Appareillage de transmission de puissance sans contact selon la revendication 5, pour alimenter en courant une palette sur laquelle est monté un axe de servomoteur d'une machine-outil qui doit venir s'y ajouter, dans lequel le premier noyau (91) est fixé à une unité statique en position adjacente à l'axe de rotation d'une table rotative (82) sur laquelle est montée la palette (83) et le second noyau (93) est fixé à la palette (83) en position coaxiale avec l'axe de rotation de la palette (83).

7. Transformateur rotatif sans contact pour la transmission de puissance ou pour la transmission de signaux entre des premier et second membres arrangés pour effectuer un mouvement rotatif relatif, comprenant une première bobine (54; 65; 104) portée par un premier élément (51; 63; 101) parmi lesdits éléments et une seconde bobine (55; --; 105) portée par un second élément (53; 63; 103) parmi lesdits éléments, et comprenant des moyens de noyaux (51, 53; 61, 63; 101, 111) faisant partie d'un chemin magnétique s'étendant à travers les première et seconde bobines et qui ne sont pas influencés par la position angulaire relative desdits deux éléments, le premier desdits deux éléments étant réalisé en une matière magnétique à haute fréquence et faisant partie desdits moyens de noyaux et possédant des branches perpendiculaires à l'axe de rotation dudit second élément, le second élément parmi lesdits deux éléments étant de forme cylindrique, caractérisé en ce que ledit premier élément (51; 61; 101) possède une configuration en U et en ce que les deux branches dudit élément, s'étendant en parallèle, enserrent avec du jeu une portion (93; 102) dudit second élément de telle sorte que l'on peut réaliser la jonction desdits deux éléments via leur mouvement linéaire relatif dans une direction perpendiculaire à l'axe du mouvement rotatif relatif.

8. Transformateur rotatif selon la revendication 7, caractérisé en ce que les deux branches parallèles (71) dudit premier élément (51; 61) sont respectivement munies d'une fente (74) s'ouvrant en direction latérale, dans laquelle vient se loger une portion terminale dudit second élément (53; 63), et en ce que le second élément (53; 63) est également réalisé en une matière magnétique à haute fréquence.

9. Transformateur rotatif selon la revendication 8, caractérisé en ce que les surfaces opposées des fentes (74) des branches (71) du premier élément en U (51; 61) et du second élément cylindrique (53; 63) présentent des conicités correspondantes.

10. Transformateur rotatif selon la revendication 9, caractérisé en ce que le premier élément en U (61) et le second élément cylindrique (63) sont reliés l'un à l'autre avec du jeu de telle sorte que, lors de l'excitation magnétique, les deux éléments peuvent venir se disposer l'un contre l'autre en ajustage serré, la première bobine (54; --) et la seconde bobine (55; 65) étant enroulées de telle sorte qu'elles sont espacées en direction radiale, mais qu'elles recouvrent la même zone axiale.

11. Transformateur rotatif selon l'une quelconque des revendications 8 à 10, caractérisé en ce que la seconde bobine (--) est arrangée sur ledit second élément cylindrique (63), tandis que la première bobine (65) est façonnée par moulage pour venir se disposer en ajustage serré par coulissement sur la surface dudit second élément (63).

12. Transformateur rotatif selon la revendication 7, caractérisé en ce que les deux branches dudit premier élément en U (101) formant un noyau enserrent une portion périphérique (303) ou une portion de bride (102) dudit second élément (103; 290) faisant saillie en direction radiale, et en ce que la seconde bobine

(105; 294) est arrangée dans ladite portion périphérique ou de bride radiale.

13. Transformateur rotatif selon la revendication 12, caractérisé en ce que la seconde bobine (105) est portée par une portion non magnétique (102) dudit second élément (103).

14. Transformateur rotatif selon la revendication 12, caractérisé en ce que la seconde bobine (105) est portée par une portion (111) dudit élément cylindrique réalisé en une matière magnétique à haute fréquence.

15. Utilisation du transformateur rotatif sans contact selon la revendication 7 dans un appareil d'usinage.

16. Utilisation dans un appareil d'usinage selon la revendication 15 dans laquelle l'appareil d'usinage est constitué d'une unité statique et d'une unité rotative manifestant une aptitude à la rotation et au retrait, l'unité rotative possédant une unité de moteur autonome, dans laquelle l'unité de moteur autonome comprend au moins: un moteur; les composants fixés à l'unité rotative de l'appareillage de transmission de puissance qui reçoit l'énergie motrice pour entraîner le moteur sans contact électrique direct; un moyen d'entraînement qui entre l'énergie motrice acheminée via l'appareillage de transmission de puissance et qui entraîne le moteur; une unité de commande de courant pour entraîner les moyens d'entraînement, qui est séparée d'une servocommande pour commander la rotation du moteur; les composants d'un premier appareil de transfert de signaux fixé à l'unité rotative pour recevoir sans contact électrique direct des commandes de couples qui doivent être alimentées à l'unité de commande de courant; des moyens de détection pour détecter des informations de fonctionnement du moteur; les composants du second appareil de transfert de signaux fixé à l'unité rotative pour transmettre des signaux de sortie provenant des moyens de détection, sans contact électrique direct;

et l'unité statique comprenant au moins: une source de courant de haute fréquence; des composants de l'appareillage de transmission de puissance fixés à l'unité statique pour transmettre l'énergie motrice provenant de la source de courant de haute fréquence à l'unité de moteur autonome sans contact électrique direct; des composants du second appareil de transfert de signaux fixé à l'unité rotative pour recevoir la sortie des moyens de détection de l'unité de moteur autonome sans contact électrique direct; une servocommande disposée sur le côté de l'unité statique constituée par une portion de la servocommande dont est séparée l'unité de commande de courant, pour générer des commandes de couples provenant à la fois d'un signal de commande alimenté par un appareil monté en amont et d'une sortie reçue par les moyens de détection; et les composants du premier appareil de transfert de signaux fixé à l'unité statique pour transmettre des commandes de couples émises par la servocommande disposée sur le côté de l'unité statique à l'unité de moteur autonome sans contact électrique direct.

17. Utilisation dans un appareil d'usinage selon la revendication 16, dans laquelle on prévoit un amplificateur de vitesse et un amplificateur de position dans la servocommande disposée sur le côté de l'unité statique pour générer une commande de couple dans le but de commander le moteur à partir de la position et de la vitesse du moteur indiquées par l'objet de la détection réalisée par le moyen de détection, et un amplificateur de courant prévu dans l'unité de moteur autonome pour commander le moteur en réponse à la commande de couple.

18. Utilisation dans un appareil d'usinage selon la revendication 16, dans laquelle on prévoit un amplificateur de vitesse et un amplificateur de position dans la servocommande disposée sur le côté de l'unité statique pour générer une commande de couple provenant de la position et de la vitesse du moteur indiquées par l'objet de la détection réalisée par les moyens de détection et à partir d'un signal de commande provenant d'un appareil monté en amont; et

dans l'unité de commande de courant, on prévoit un amplificateur de courant pour commander le moteur en réponse à la commande de courant, et un générateur de commande de courant pour générer une commande de courant à la fois à partir de la commande de couple et de la phase du moteur indiquées par- l'objet de la détection réalisée par les moyens de détection.

19. Utilisation dans un appareil d'usinage selon la revendication 15, dans laquelle on prévoit plusieurs unités de moteurs autonomes combinées en plusieurs étages, qui reçoivent des commandes de couples à partir d'une servocommande disposée sur le côté de l'unité statique, l'alimentation en courant à partir de l'unité statique en direction de chaque étage des unités de moteurs autonomes et la communication des signaux de données et des signaux de commande entre la servocommande disposée sur le côté de l'unité statique et l'unité de commande de courant de chaque étage étant réalisées via un appareillage de transmission de puissance et via un appareil de transfert de signaux prévus entre l'unité statique et le premier étage des unités de moteurs autonomes, et entre les unités de moteurs autonomes dans des étages individuels.

20. Utilisation dans un appareil d'usinage selon l'une quelconque des revendications 17 à 19, dans laquelle l'appareillage de transmission de puissance et l'appareil de transfert de signaux sont construits sous forme d'une unité intégrée.

21. Utilisation dans un appareil d'usinage selon la revendication 16, dans laquelle l'unité de moteur autonome entraîne de manière réglable un élément mobile monté dans cette unité de moteur autonome ou encore entraîne de manière réglable le mécanisme de cette unité de moteur autonome elle-même.

22. Utilisation dans un appareil d'usinage selon la revendication 16, dans laquelle l'appareil d'usinage est une machine-outil, un robot ou encore des équipements qui y sont liés.

23. Utilisation dans un appareil d'usinage selon la revendication 21, dans laquelle l'unité de moteur autonome est construite sous forme d'une unité capable d'être retirée de l'appareil d'usinage.

24. Utilisation dans un appareil d'usinage selon la revendication 15, dans laquelle l'appareil d'usinage englobe un appareil rotatif et l'appareillage de transmission de puissance, ainsi que l'appareil de transfert de signaux sont montés en position coaxiale par rapport à l'axe de rotation de l'appareil rotatif.

25. Utilisation dans un appareil d'usinage selon la revendication 24, dans laquelle l'appareil rotatif possède une charge électrique montée à l'extrémité de son arbre de rotation, le câblage depuis la seconde bobine de l'appareillage de transmission de puissance jusqu'à l'extrémité de l'arbre de rotation et le câblage depuis le composant fixé à l'unité rotative de l'appareil de transfert de signaux jusqu'à l'extrémité de l'arbre de rotation étant arrangés dans une rainure prévue sur la circonférence externe de l'arbre de rotation dans la direction de l'axe de l'arbre ou encore dans une portion creuse d'un arbre de rotation creux.

26. Utilisation dans un appareil d'usinage selon la revendication 25, dans laquelle l'appareil rotatif est un moteur; le second noyau de l'appareillage de transmission de puissance est prévu sur l'arbre de rotation supporté par des paliers à ses deux extrémités; le premier noyau est prévu pour être fixé à l'unité statique et face au second noyau à travers un espace libre; et l'appareil de transfert de signaux est prévu sur la périphérie externe de l'arbre de rotation à un endroit faisant face à l'unité statique.

27. Utilisation dans un appareil d'usinage selon la revendication 25, dans laquelle l'appareil rotatif est un arrangement à réduction; le second noyau de l'appareillage de transmission de puissance est prévu sur l'arbre de sortie à vitesse réglable supporté par des paliers à ses extrémités; le premier noyau est prévu pour être fixé à l'unité statique en faisant face au second noyau à travers un espace libre; et l'appareil de transfert de signaux selon la revendication 12 est prévu sur la périphérie externe de l'arbre de sortie à vitesse réglable et dans une position faisant face à l'unité statique.

28. Procédé de réglage d'une alimentation en courant sans contact pour un moteur, qui peut être appliqué à l'appareil d'usinage tel que décrit à la revendication 16, dans lequel

la servocommande disposée sur le côté de l'unité statique génère une commande de couple provenant à la fois d'un signal de commande émis par un appareil prévu en amont et de l'objet de la détection réalisée par les moyens de détection, et fournit la commande de couple à une unité de moteur autonome, et
l'unité de moteur autonome entraîne un moteur en réponse à la commande de couple fournie par la servocommande disposée sur le côté de l'unité statique.

29. Procédé de réglage d'une alimentation en courant sans contact selon la revendication 28, dans lequel

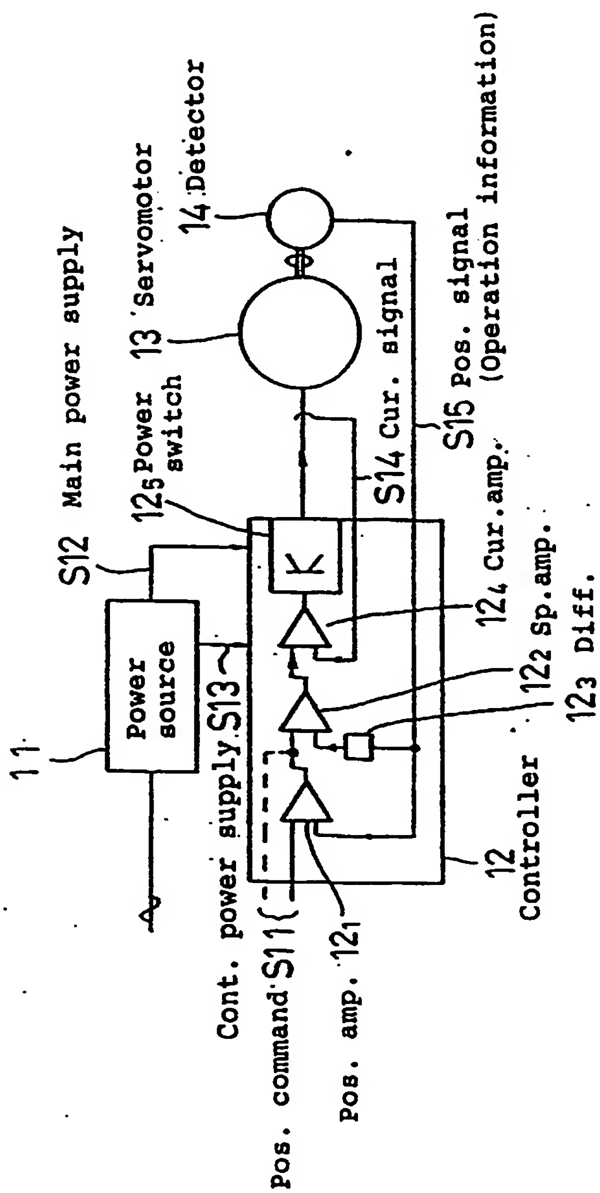
la servocommande disposée sur le côté de l'unité statique génère une commande de couple provenant à la fois d'un signal de commande émis par un appareil monté en amont, ainsi que d'une vitesse et d'une position du moteur indiquées par l'objet de la détection réalisée par les moyens de détection, et transmet la commande de couple à une unité de moteur autonome, et
l'unité de moteur autonome entraîne un moteur en utilisant la commande de couple fournie par la servocommande disposée sur le côté de l'unité statique à titre de commande de courant.

30. Procédé de réglage d'une alimentation en courant sans contact selon la revendication 28, dans lequel

la servocommande disposée sur le côté de l'unité statique génère une commande de couple provenant à la fois du signal de commande entré à partir d'un appareil monté en amont, ainsi que d'une vitesse et d'une position du moteur indiquées par l'objet de la détection réalisée par les moyens de détection, et transmet la commande de couple à une unité de moteur autonome, et
l'unité de moteur autonome génère une commande de courant provenant à la fois d'une

phase du moteur indiquée par l'objet de la détection réalisée par les moyens de détection et de la commande de couple fournie par la servocommande disposée sur le côté de l'unité statique, et entraîne un moteur.

Fig. 1



Main power supply
S12
11
Power source
Cont. power supply S13
Pos. command S11
Pos. amp. 12₁
12₅ Power switch
13 Servomotor
14 Detector
S14 Cur. signal
S15 Pos. signal (Operation information)
12₄ Cur. amp.
12₂ Sp. amp.
12₃ Diff.
12 Controller

Fig. 2

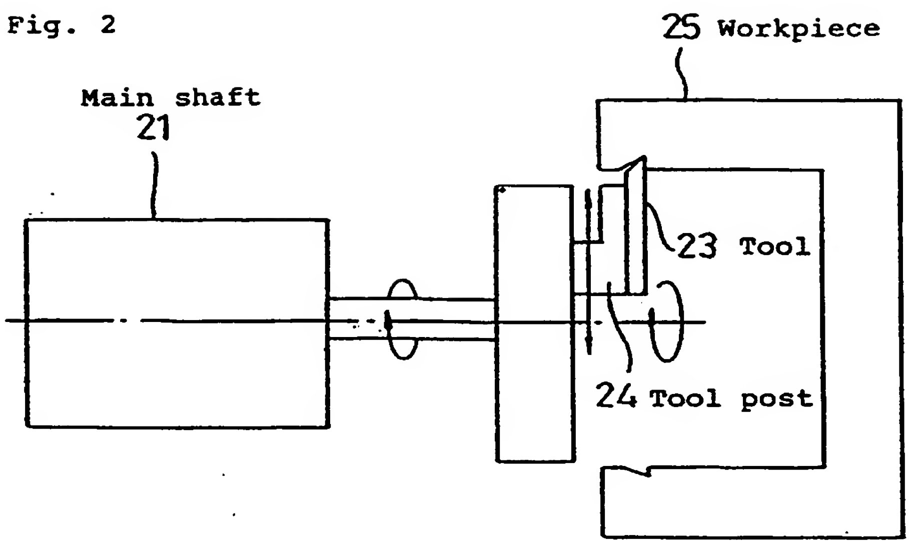

25 Workpiece
Main shaft
21
23 Tool
24 Tool post

Fig. 3

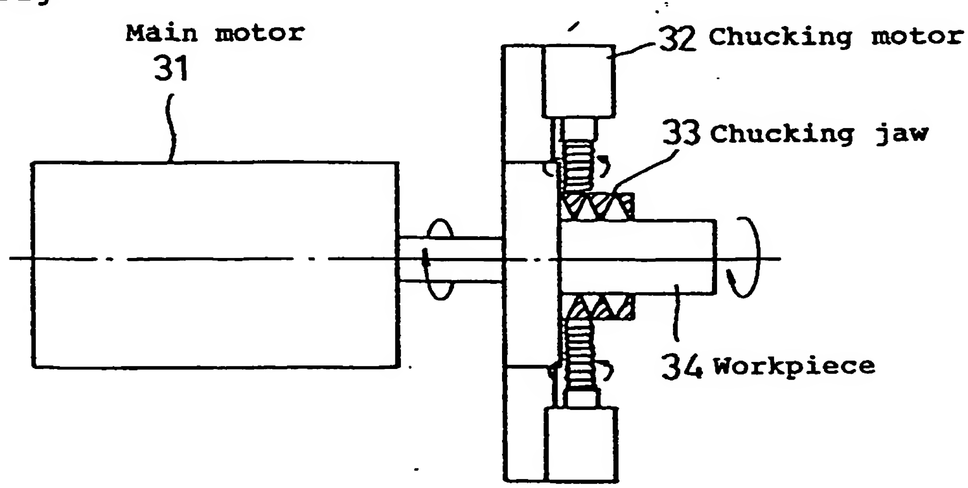
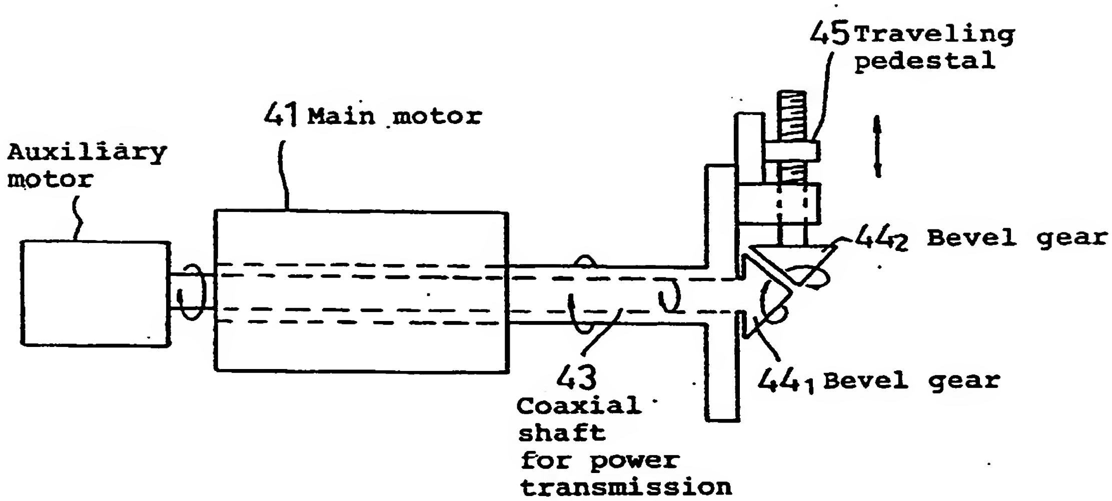

Main motor
31
32 Chucking motor
33 Chucking jaw
34 Workpiece

Fig. 4



45 Traveling pedestal
41 Main motor
Auxiliary motor
44₂ Bevel gear
43
Coaxial shaft for power transmission
44₁ Bevel gear

Fig. 5

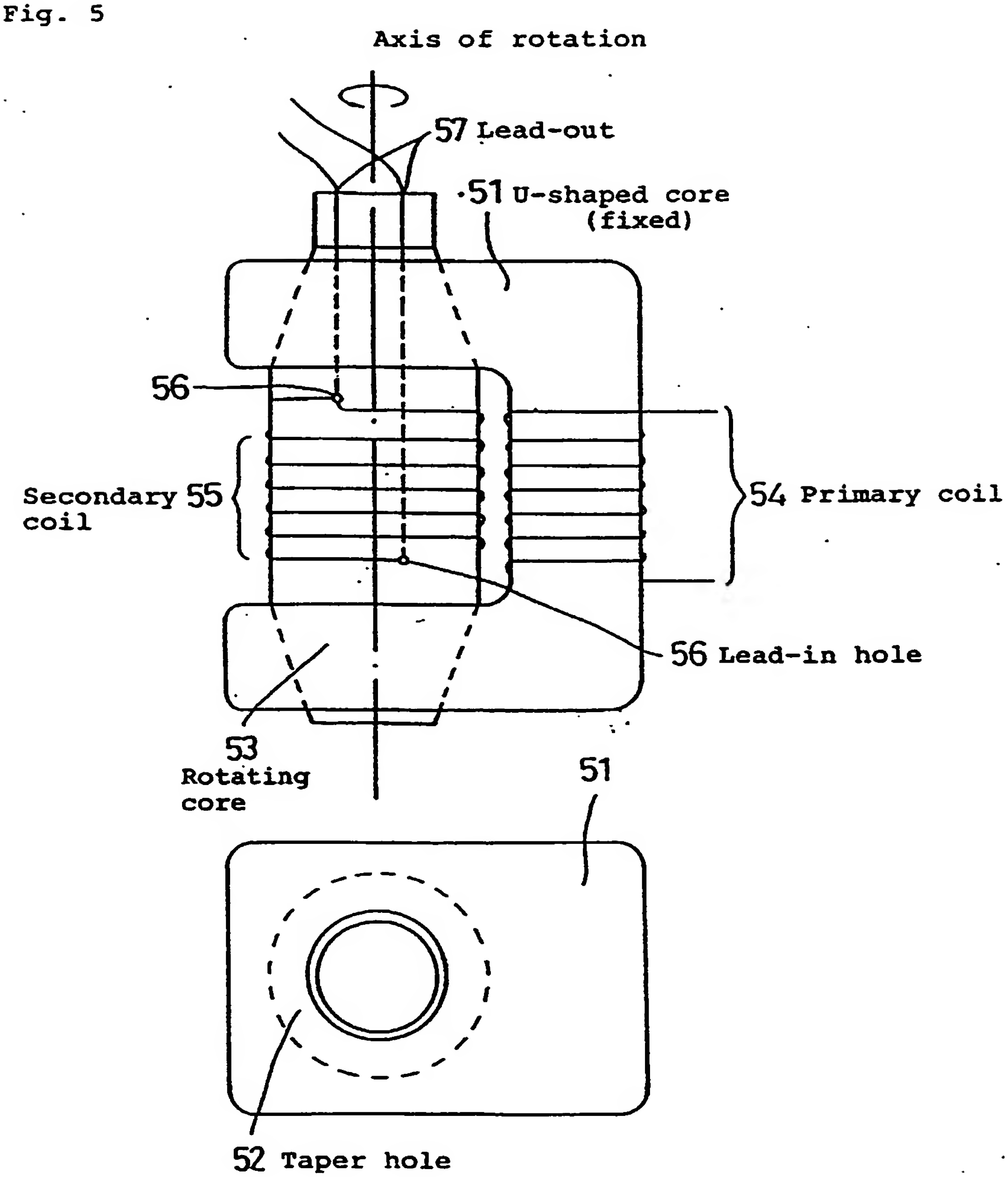

Axis of rotation
57 Lead-out
51 U-shaped core
(fixed)
56
Secondary 55
coil
54 Primary coil
56 Lead-in hole
53
Rotating
core
51
52 Taper hole

Fig. 6

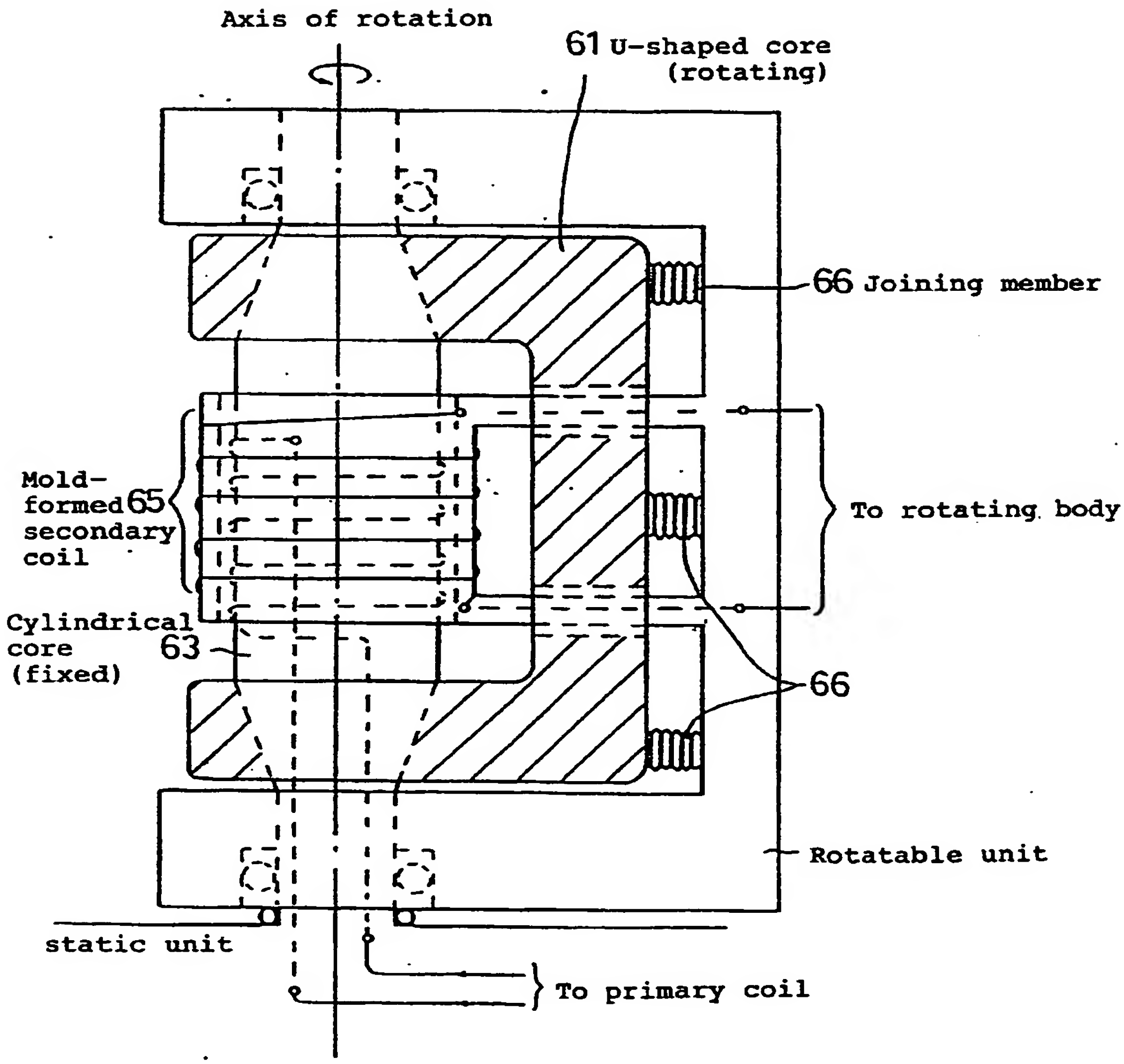

Axis of rotation
61 U-shaped core (rotating)
66 Joining member
Mold-formed 65 secondary coil
To rotating body
Cylindrical core (fixed) 63
66
Rotatable unit
static unit
To primary coil

Fig. 7

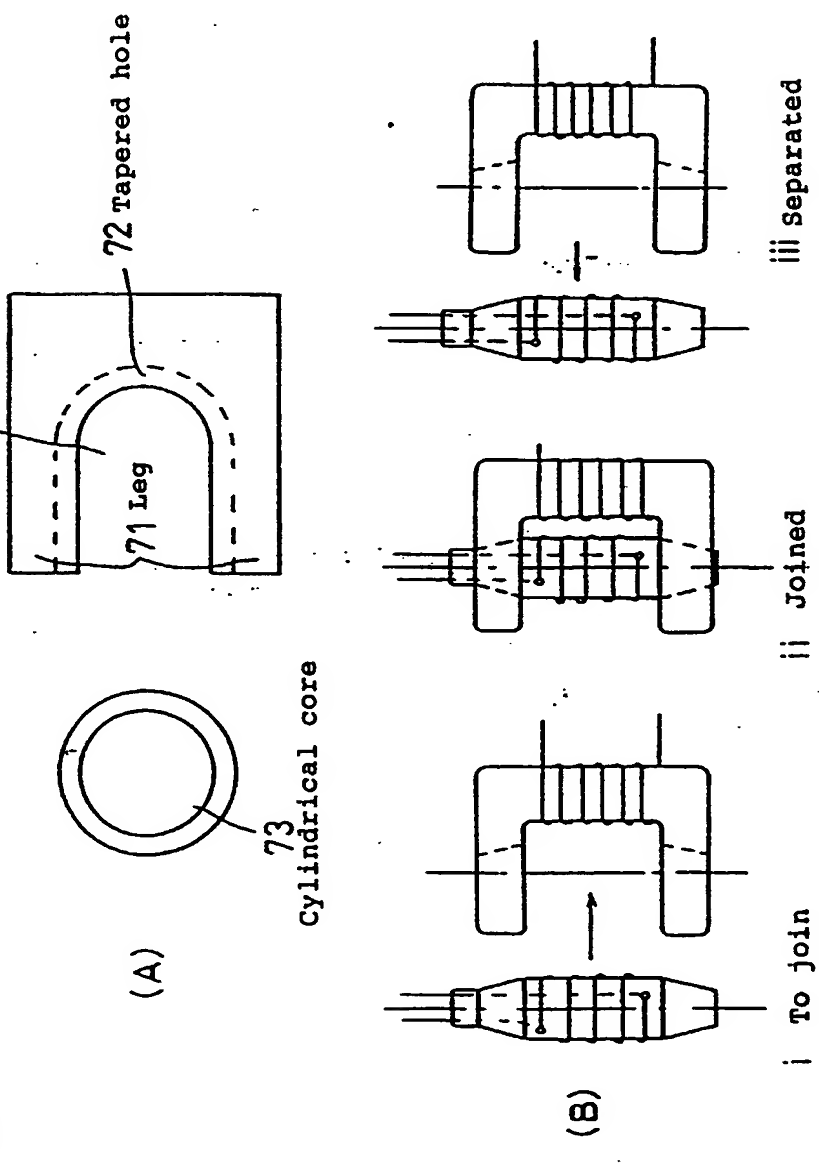
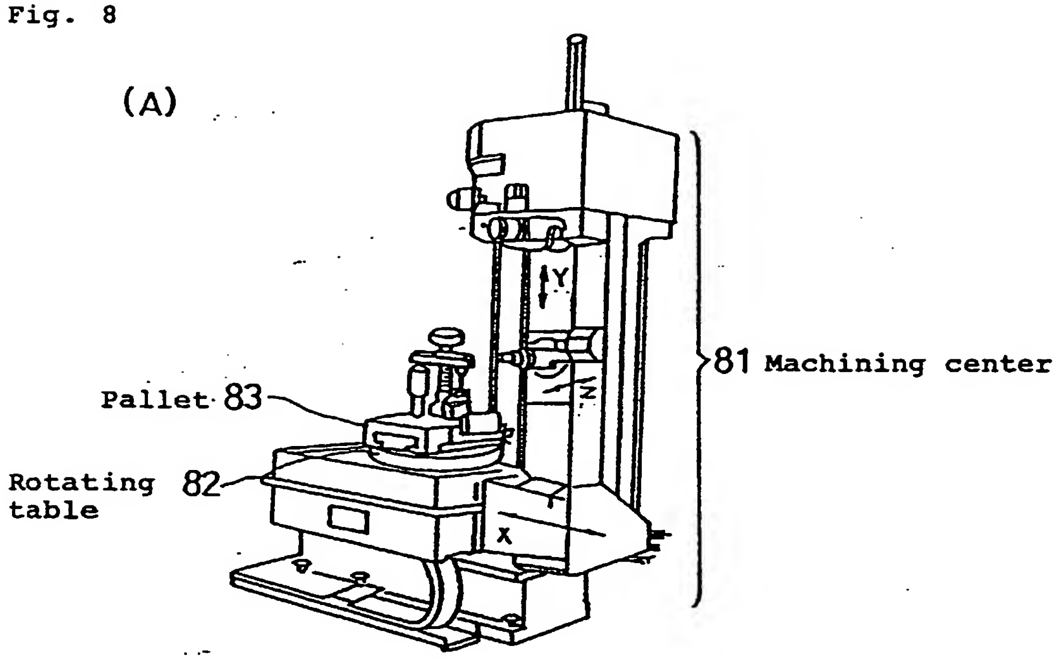

(A)
74 Notch
72 Tapered hole
71 Leg
73
Cylindrical core
(B)
i To join
ii Joined
iii Separated

Fig. 8

(A)


Y
Z
X
81 Machining center
Pallet 83
Rotating table 82

(B)

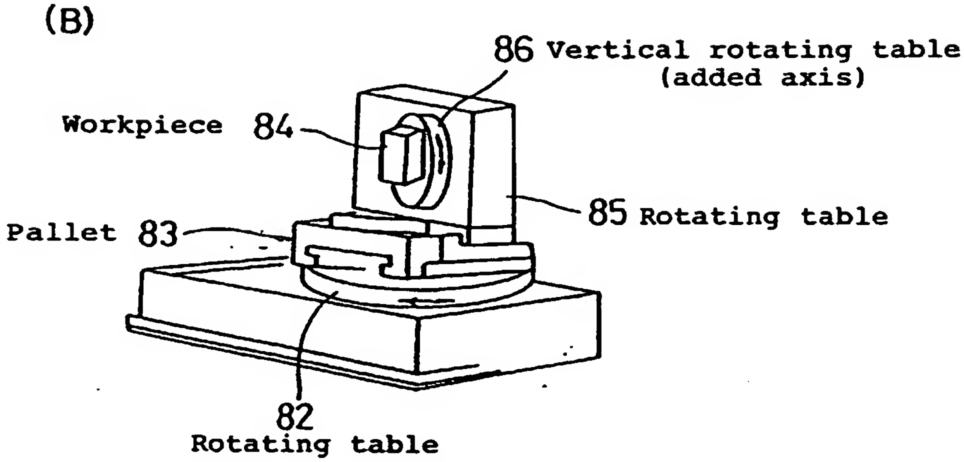

86 Vertical rotating table (added axis)
Workpiece 84
85 Rotating table
Pallet 83
82 Rotating table

Fig. 9

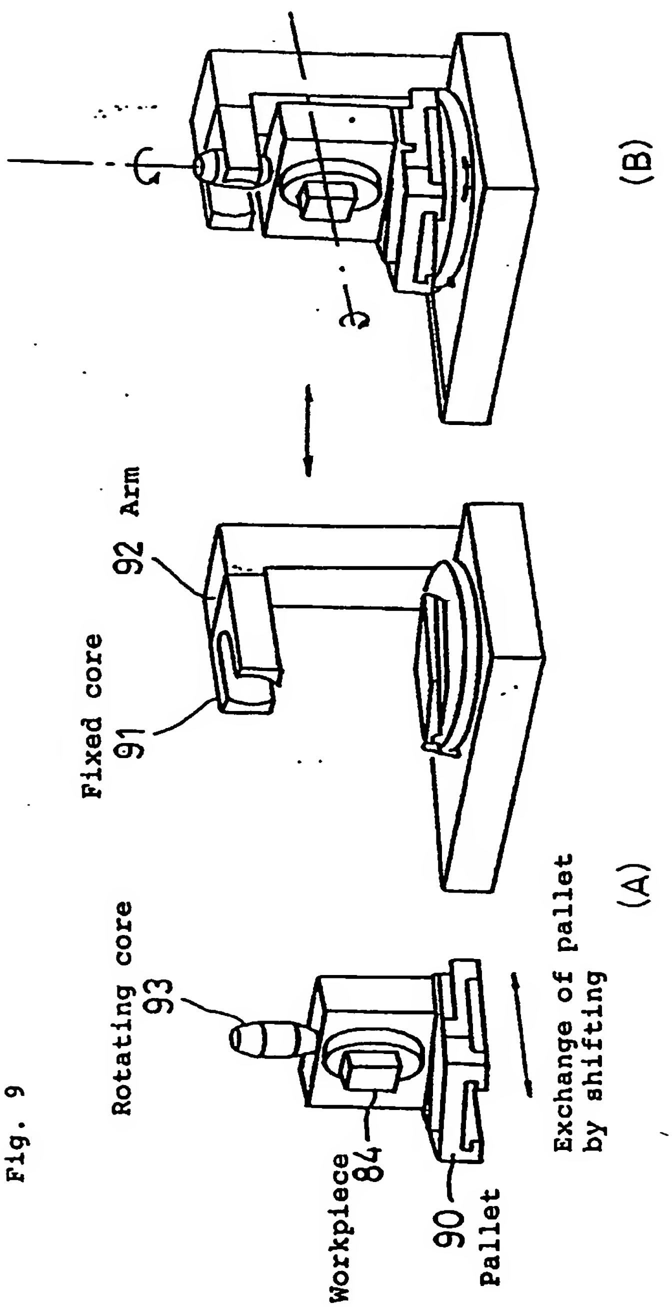

Rotating core
93
Workpiece
84
90
Pallet
Exchange of pallet
by shifting
(A)
Fixed core
91
92
Arm
(B)

Fig. 10

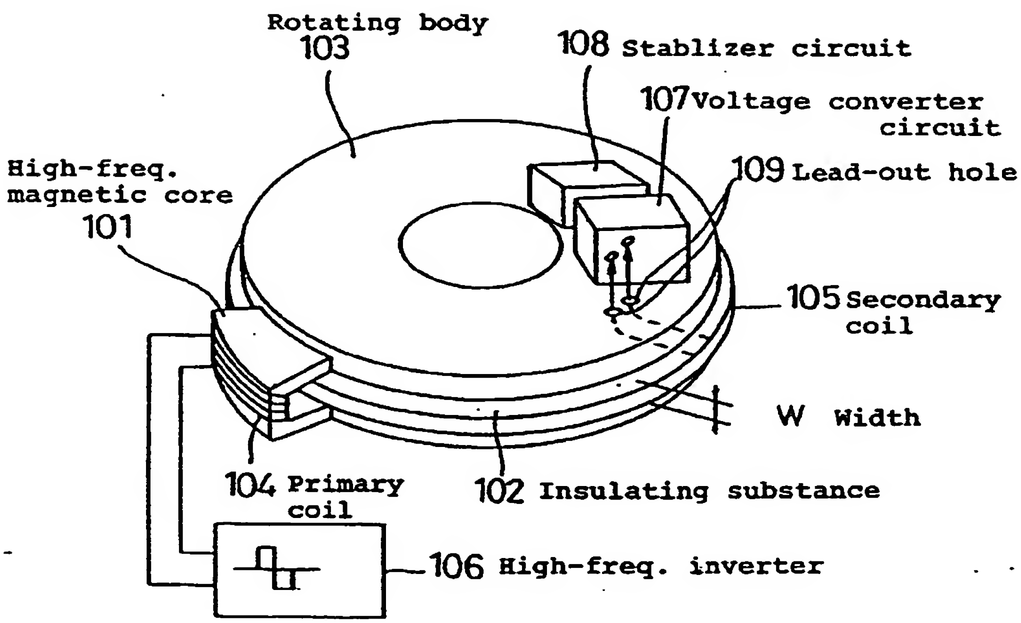

Rotating body
103
108 Stablizer circuit
107 Voltage converter circuit
109 Lead-out hole
High-freq. magnetic core
101
105 Secondary coil
W Width
104 Primary coil
102 Insulating substance
106 High-freq. inverter

Fig. 11

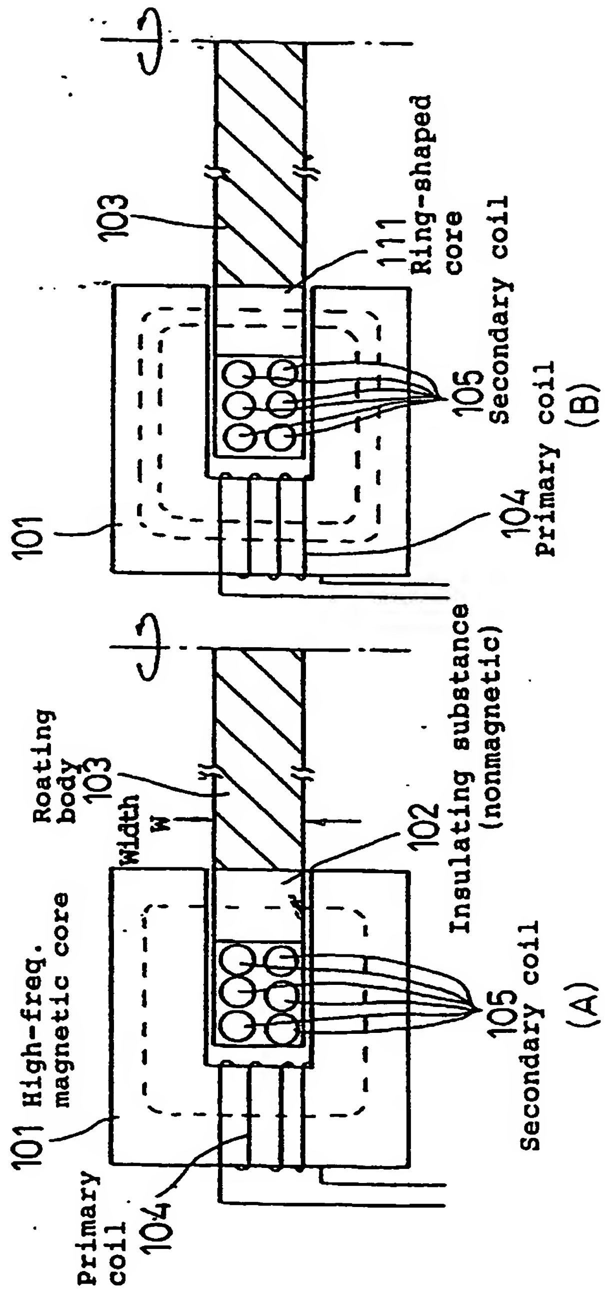

101 High-freq. magnetic core
Primary coil
104
Roating body
103
Width W
102
Insulating substance (nonmagnetic)
105
Secondary coil
(A)
101
103
111 Ring-shaped core
105
Secondary coil
104
Primary coil
(B)

Fig. 12

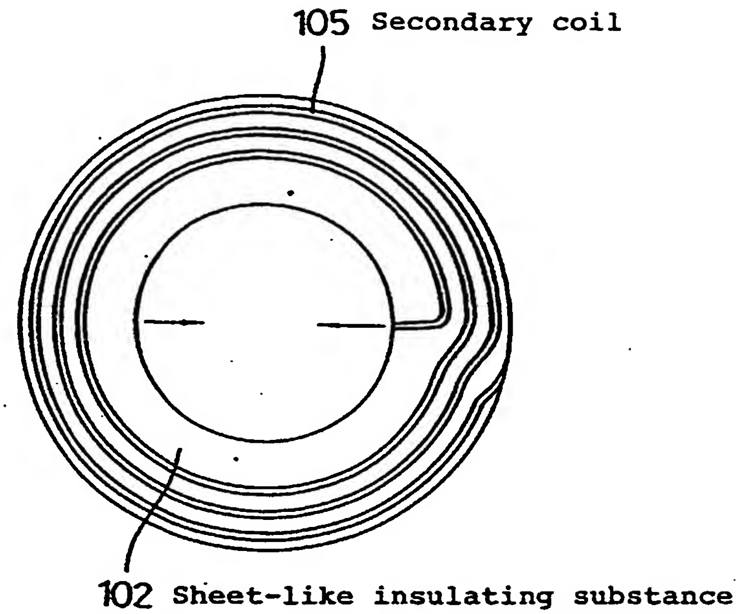

105 Secondary coil
102 Sheet-like insulating substance

Fig. 13

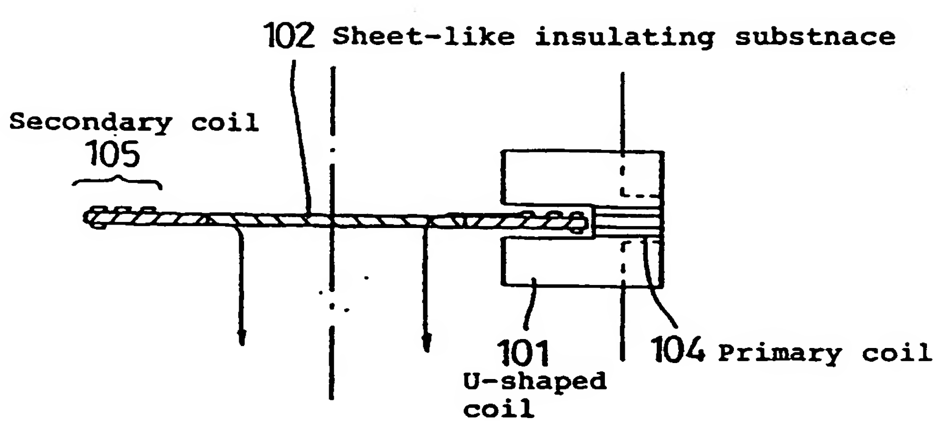

102 Sheet-like insulating substnace
Secondary coil
105
101
U-shaped
coil
104 Primary coil

Fig. 14

(A)

(B)

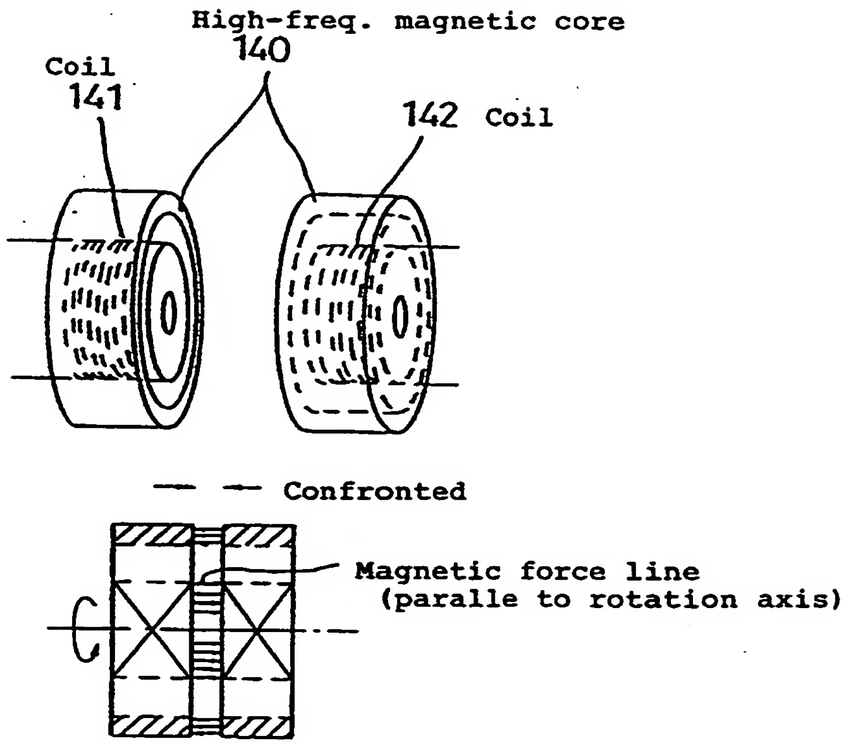
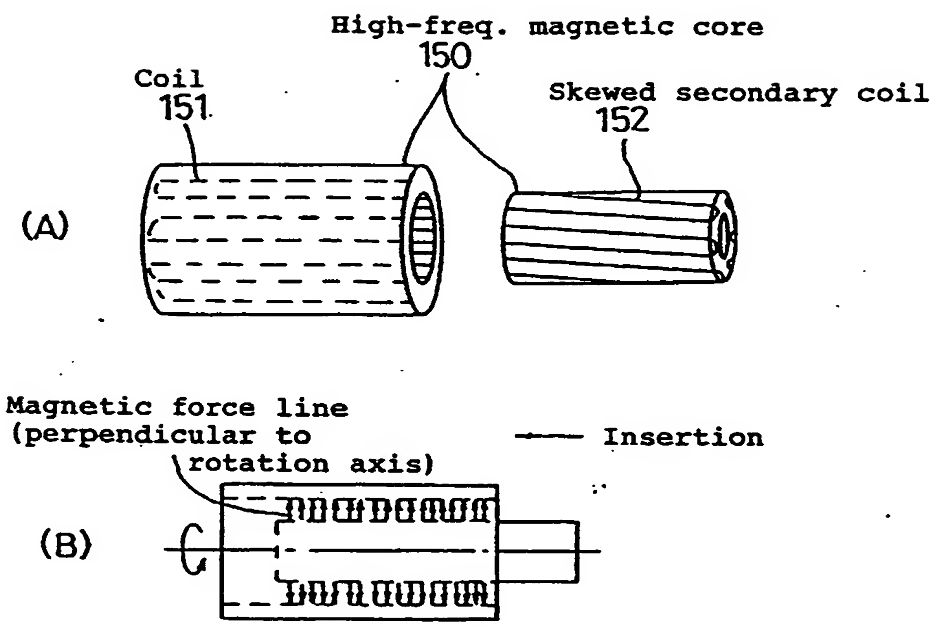

High-freq. magnetic core
140
Coil
141
142 Coil
Confronted
Magnetic force line
(paralle to rotation axis)

Fig. 15



High-freq. magnetic core
150
Coil
151
Skewed secondary coil
152
(A)
Magnetic force line
(perpendicular to
rotation axis)
Insertion
(B)

Fig. 16

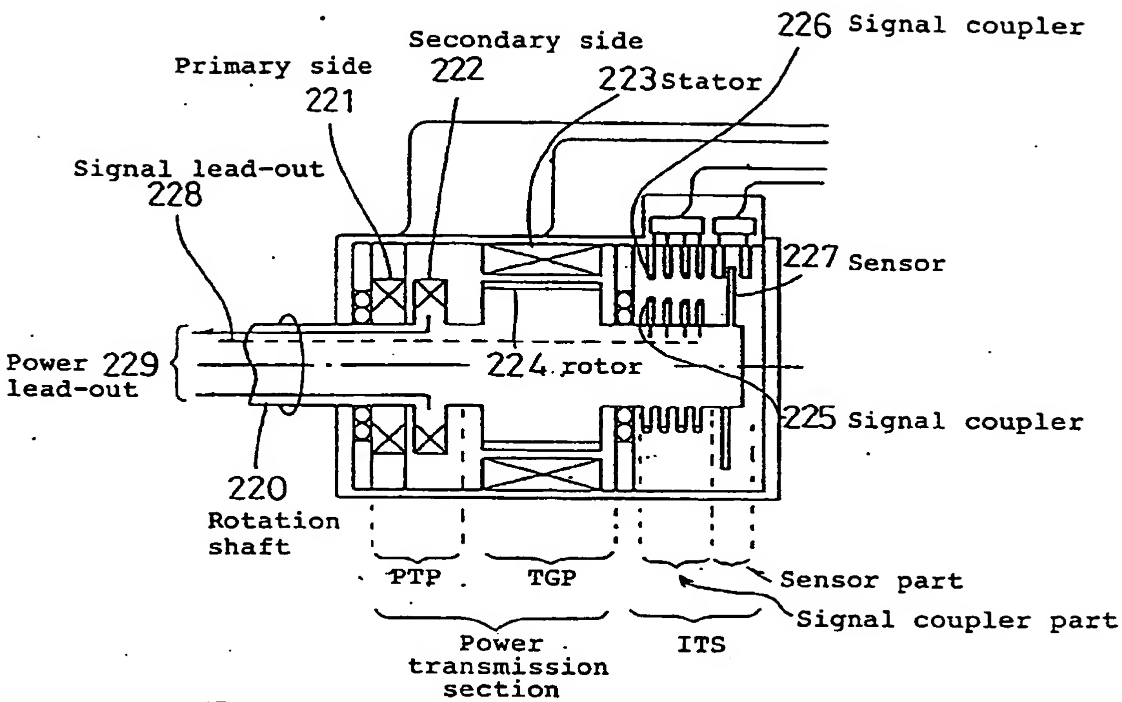

226 Signal coupler
Secondary side
222
Primary side
221
223 Stator
Signal lead-out
228
227 Sensor
Power 229
lead-out
224 rotor
225 Signal coupler
220
Rotation
shaft
PTP
TGP
Sensor part
Signal coupler part
Power
transmission
section
ITS

Fig. 17

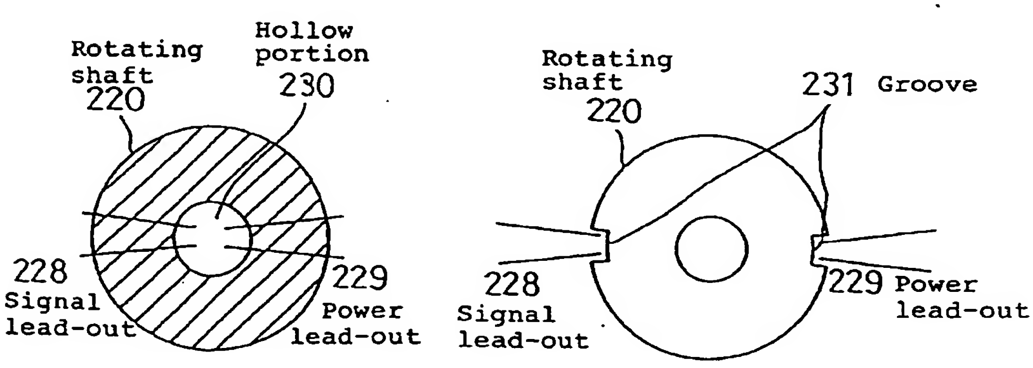

Rotating
shaft
220
Hollow
portion
230
228
Signal
lead-out
229
Power
lead-out
Rotating
shaft
220
231 Groove
228
Signal
lead-out
229 Power
lead-out

Fig. 18

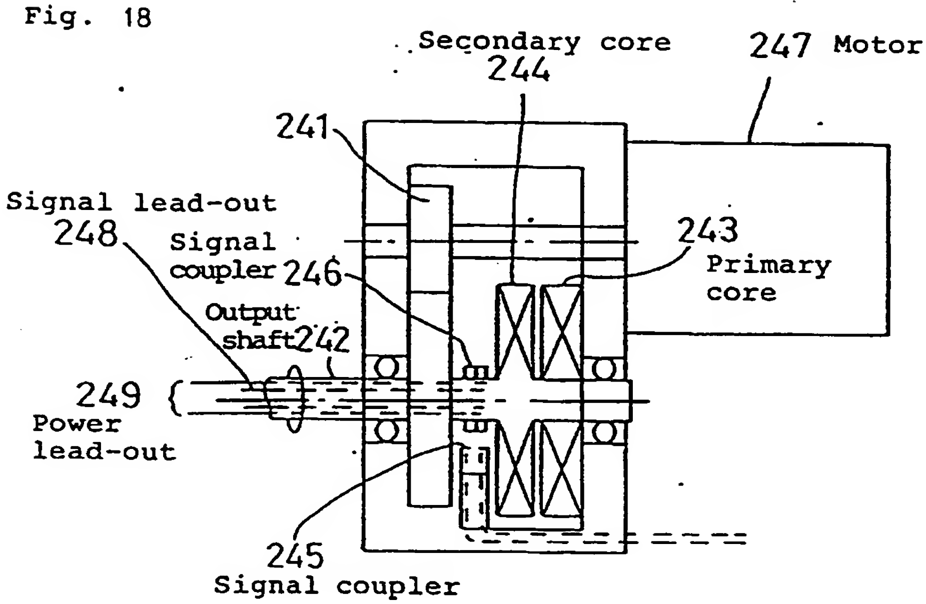

Secondary core
244
247 Motor
241
Signal lead-out
248
Signal
coupler 246
243
Primary
core
Output
shaft 242
249
Power
lead-out
245
Signal coupler

Fig. 19

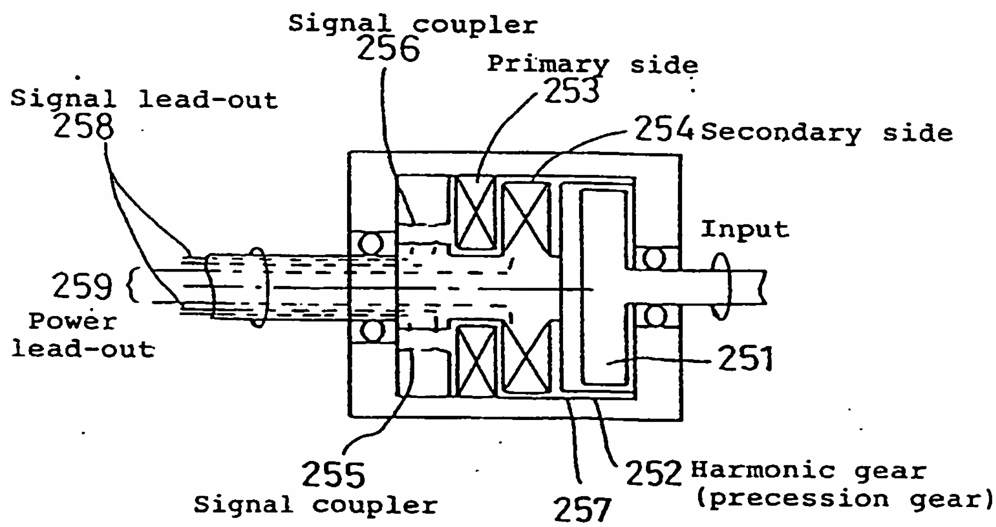

Signal coupler
256
Primary side
253
Signal lead-out
258
254 Secondary side
Input
259
Power
lead-out
251
255
Signal coupler
257
252 Harmonic gear
(precession gear)

Fig. 20

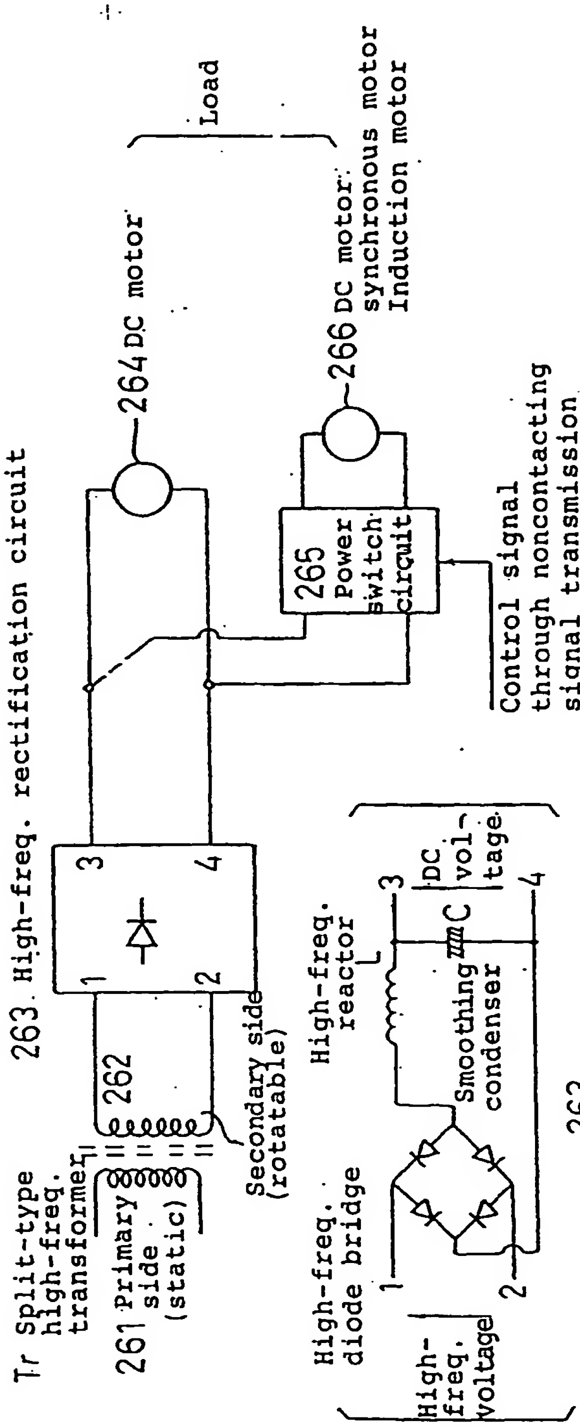

Tr Split-type high-freq. transformer
261 Primary side (static)
262
Secondary side (rotatable)
263 High-freq. rectification circuit
1
2
3
4
264 DC motor
265 Power switch circuit
266 DC motor: synchronous motor Induction motor
Load
Control signal through noncontacting signal transmission
High-freq. diode bridge
High-freq. reactor
L
Smoothing condenser
C
High-freq. voltage
DC voltage
263

Fig. 21

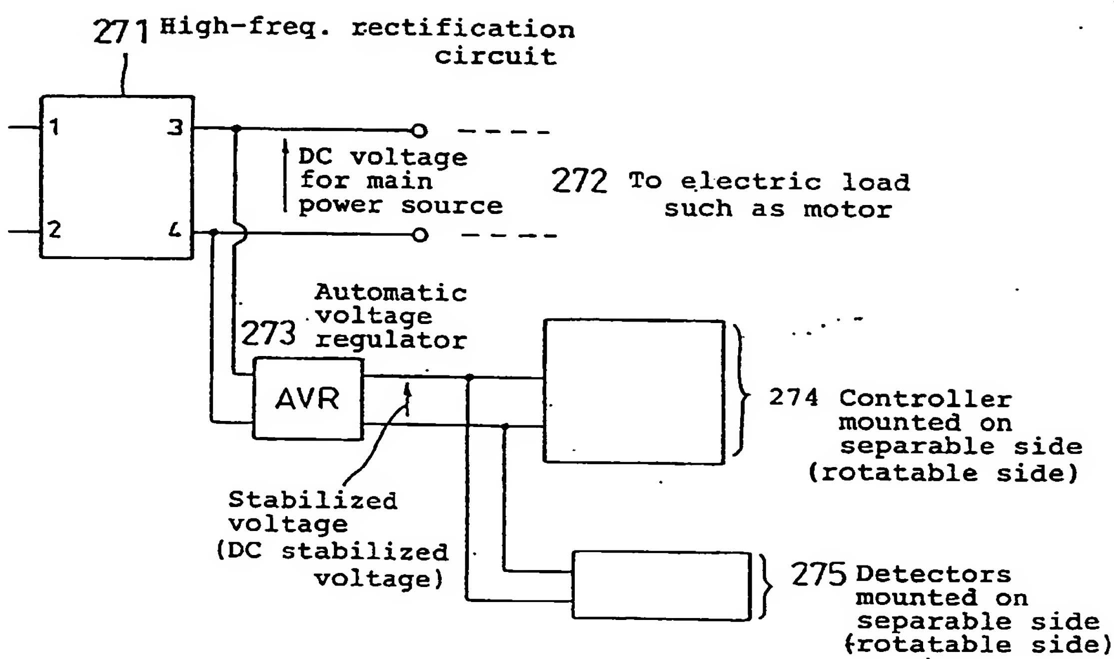

271 High-freq. rectification circuit
1
2
3
4
DC voltage for main power source
272 To electric load such as motor
Automatic voltage regulator
273
AVR
274 Controller mounted on separable side (rotatable side)
Stabilized voltage (DC stabilized voltage)
275 Detectors mounted on separable side (rotatable side)

Fig. 22

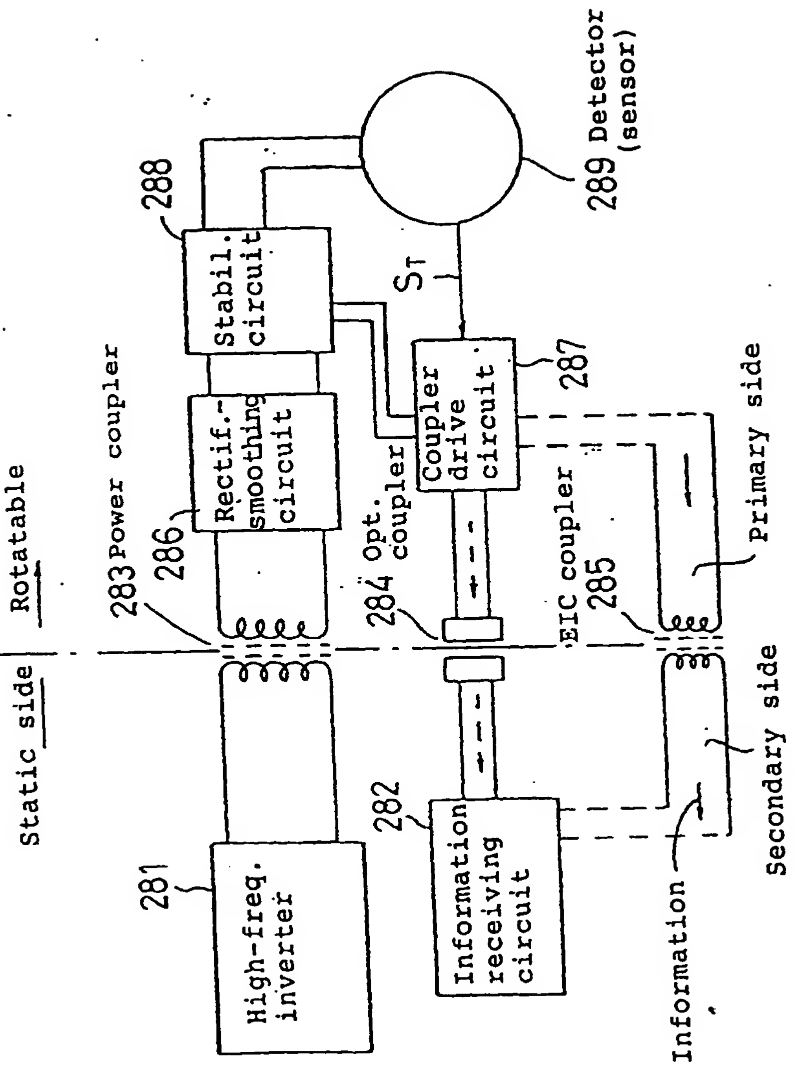

Static side
Rotatable
283 Power coupler
281
High-freq. inverter
286
Rectif.-smoothing circuit
288
Stabil. circuit
289 Detector (sensor)
S_T
287
Coupler drive circuit
284 Opt. coupler
282
Information receiving circuit
EIC coupler
285
Primary side
Secondary side
Information

Fig. 23

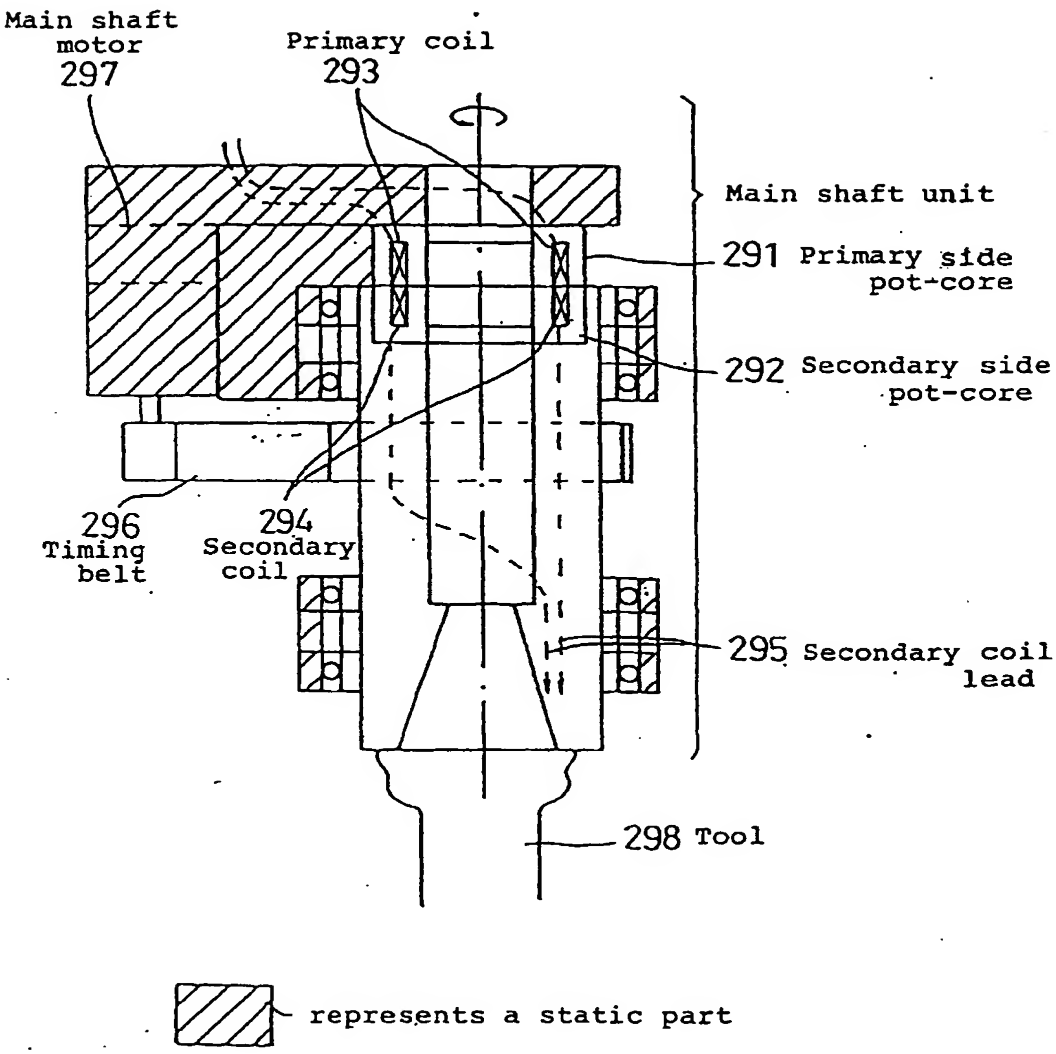
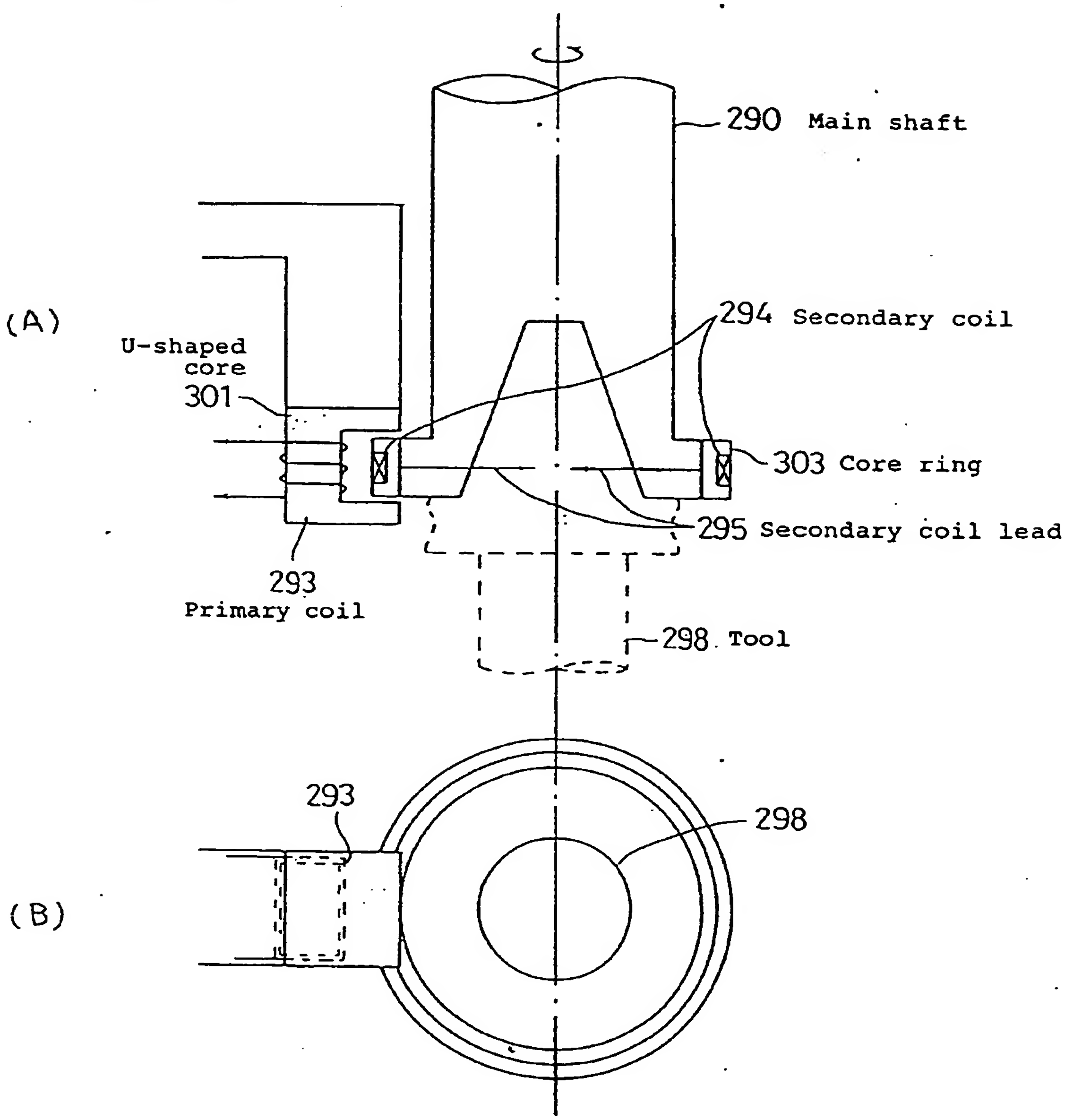

Main shaft motor
297
Primary coil
293
Main shaft unit
291 Primary side pot-core
292 Secondary side pot-core
296 Timing belt
294 Secondary coil
295 Secondary coil lead
298 Tool
represents a static part

Fig. 24



(A)
290 Main shaft
294 Secondary coil
U-shaped core
301
303 Core ring
295 Secondary coil lead
293
Primary coil
298 Tool
(B)
293
298

Fig. 25

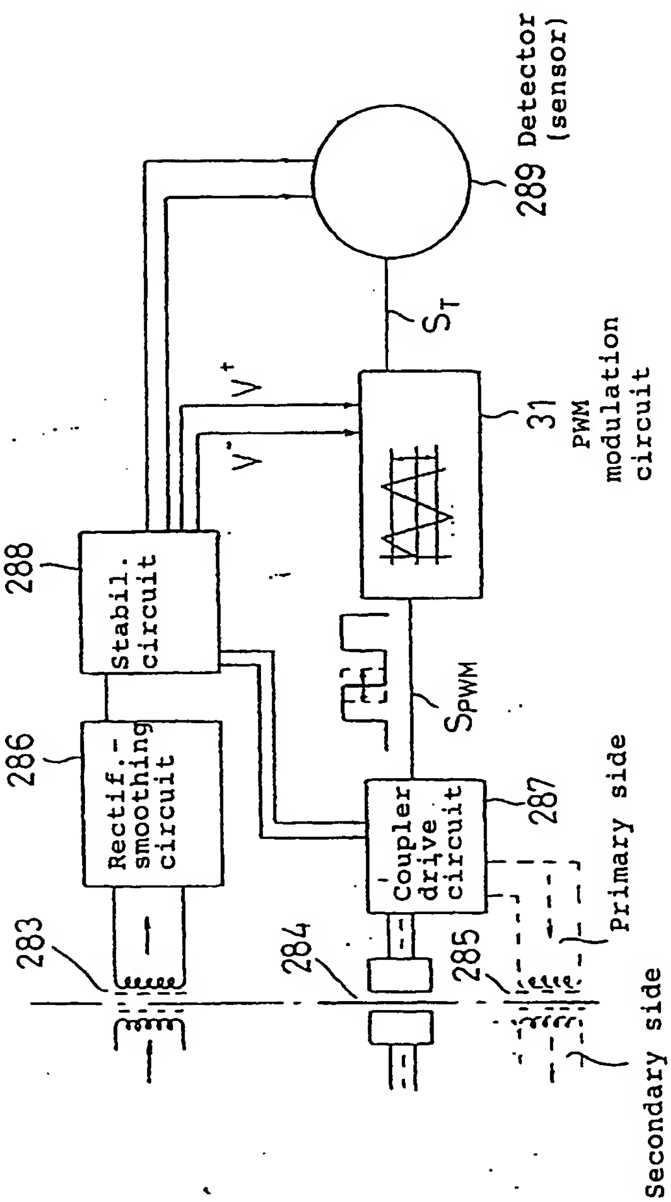

Detector (sensor)
289
S_T
V^+
V^-
PWM modulation circuit
31
288
Stabil. circuit
286
Rectif.-smoothing circuit
S_{PWM}
Coupler drive circuit
287
Primary side
283
284
285
Secondary side

Fig. 26

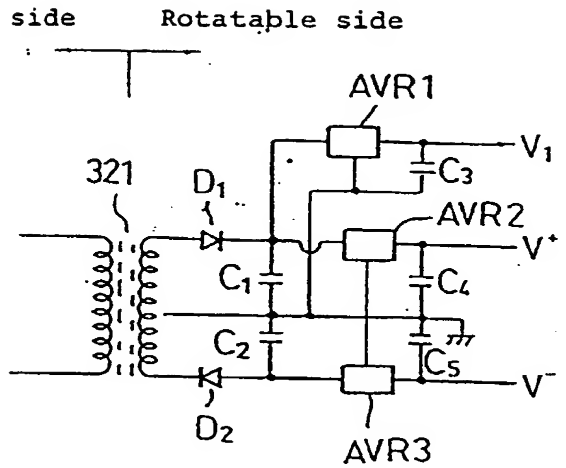

Static side
Rotatable side
AVR1
321
D1
C3
AVR2
V1
V+
C1
C4
C2
C5
V-
D2
AVR3

Fig. 27

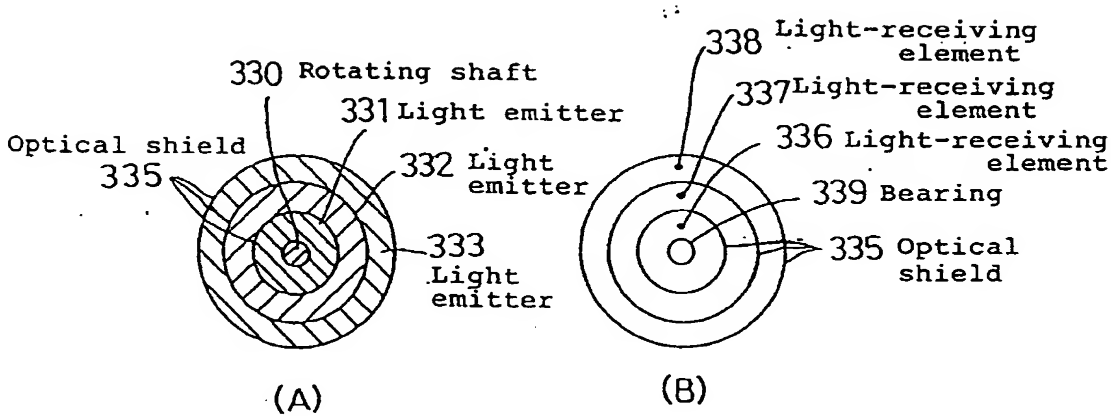
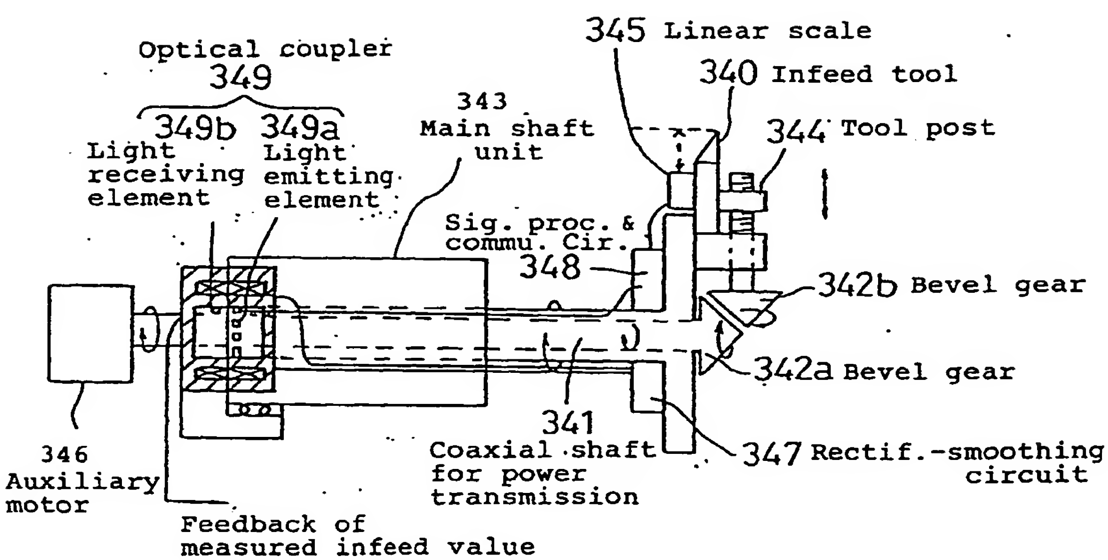

330 Rotating shaft
331 Light emitter
Optical shield
335
332 Light emitter
333 Light emitter
(A)
338 Light-receiving element
337 Light-receiving element
336 Light-receiving element
339 Bearing
335 Optical shield
(B)

Fig. 28



345 Linear scale
Optical coupler
349
340 Infeed tool
343
Main shaft
unit
344 Tool post
349b
Light
receiving
element
349a
Light
emitting
element
Sig. proc. &
commu. Cir.
348
342b Bevel gear
342a Bevel gear
341
Coaxial shaft
for power
transmission
347 Rectif.-smoothing
circuit
346
Auxiliary
motor
Feedback of
measured infeed value

Fig. 29

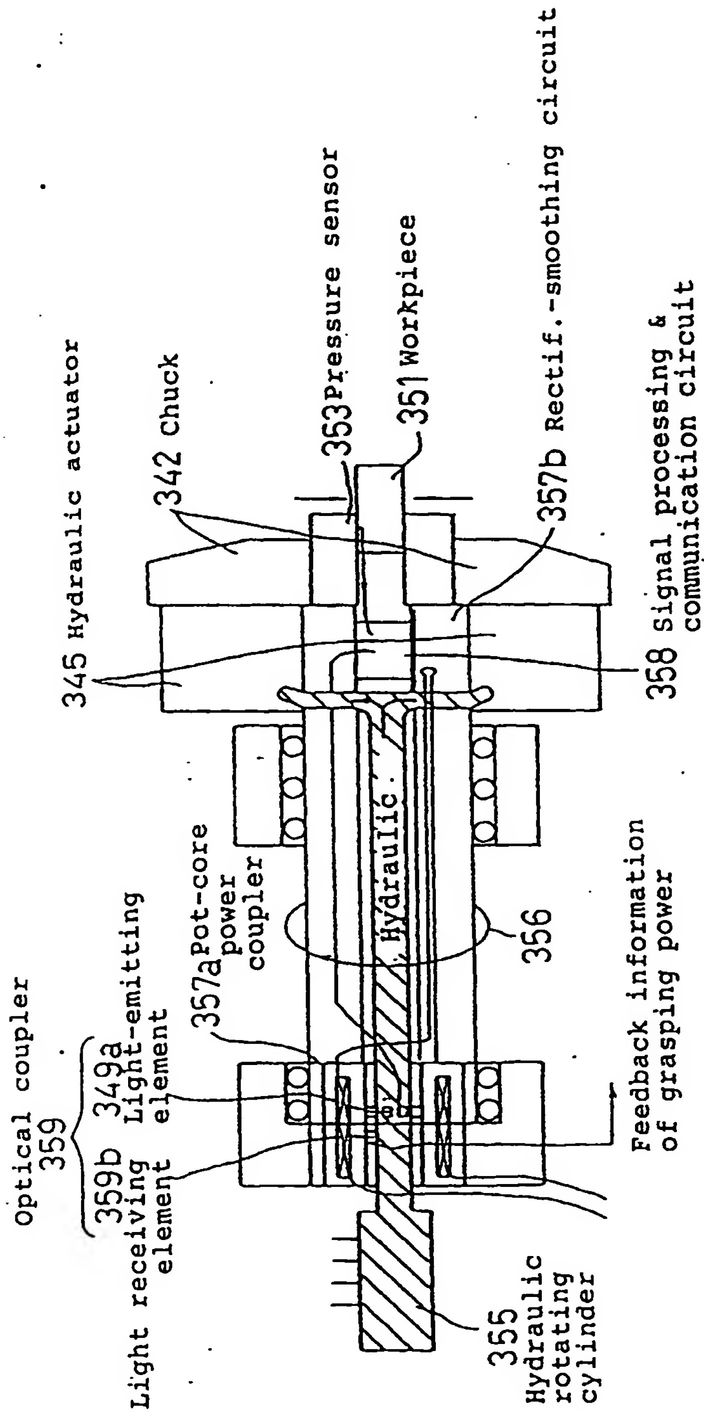

345 Hydraulic actuator
342 Chuck
353 Pressure sensor
351 Workpiece
357b Rectif.-smoothing circuit
358 Signal processing & communication circuit
Optical coupler
359
359b Light receiving element
349a Light-emitting element
357a Pot-core power coupler
Hydraulic
356
Feedback information of grasping power
355 Hydraulic rotating cylinder

Fig. 30

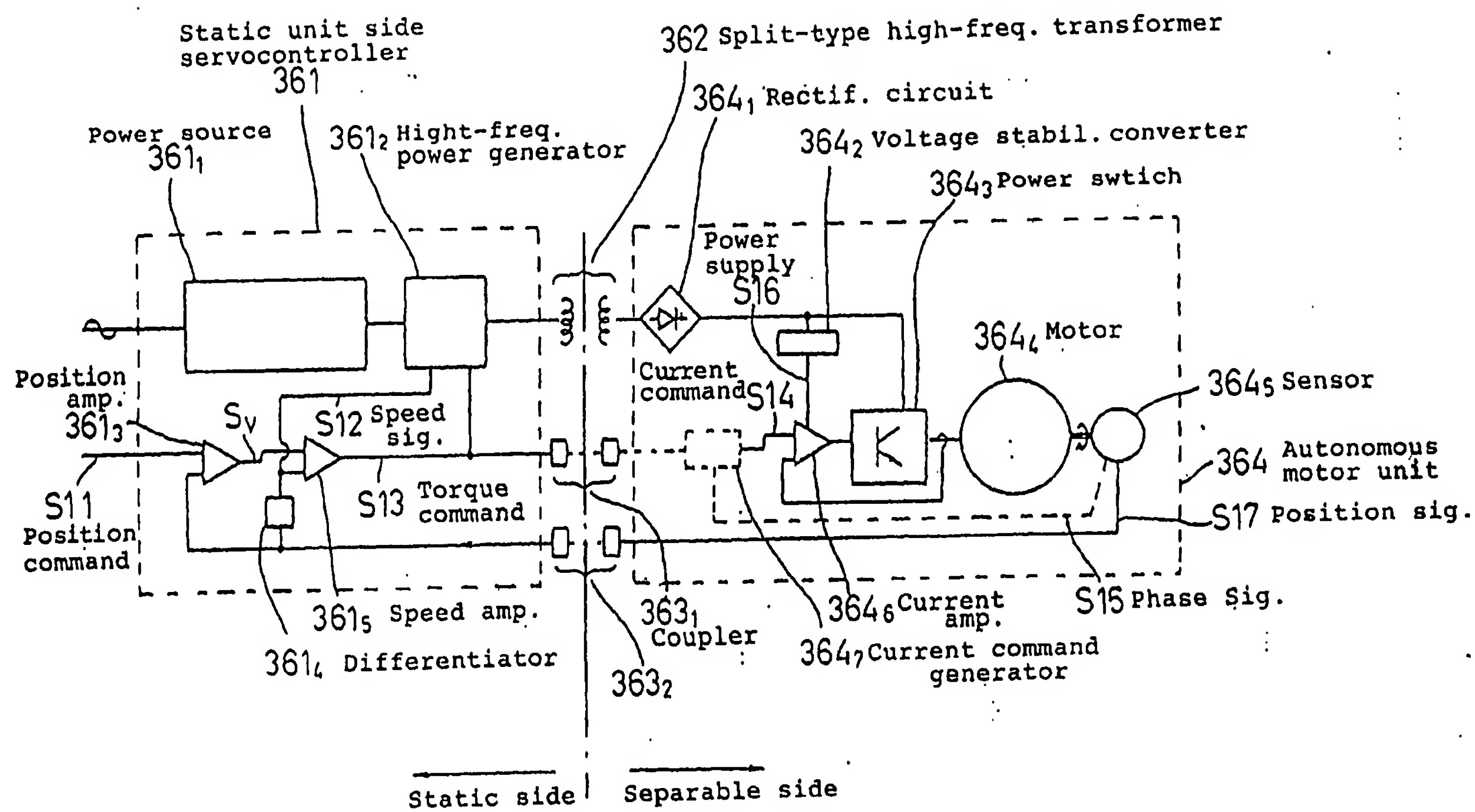

Static unit side servocontroller
361
Power source
361_1
361_2 Hight-freq. power generator
Position amp.
361_3
S_V
S12 Speed sig.
S13 Torque command
S11 Position command
361_5 Speed amp.
361_4 Differentiator
362 Split-type high-freq. transformer
364_1 Rectif. circuit
364_2 Voltage stabil. converter
364_3 Power swtich
Power supply
S16
Current command
S14
364_4 Motor
364_5 Sensor
364 Autonomous motor unit
S17 Position sig.
S15 Phase Sig.
364_6 Current amp.
364_7 Current command generator
363_1 Coupler
363_2
Static side
Separable side

Fig. 31

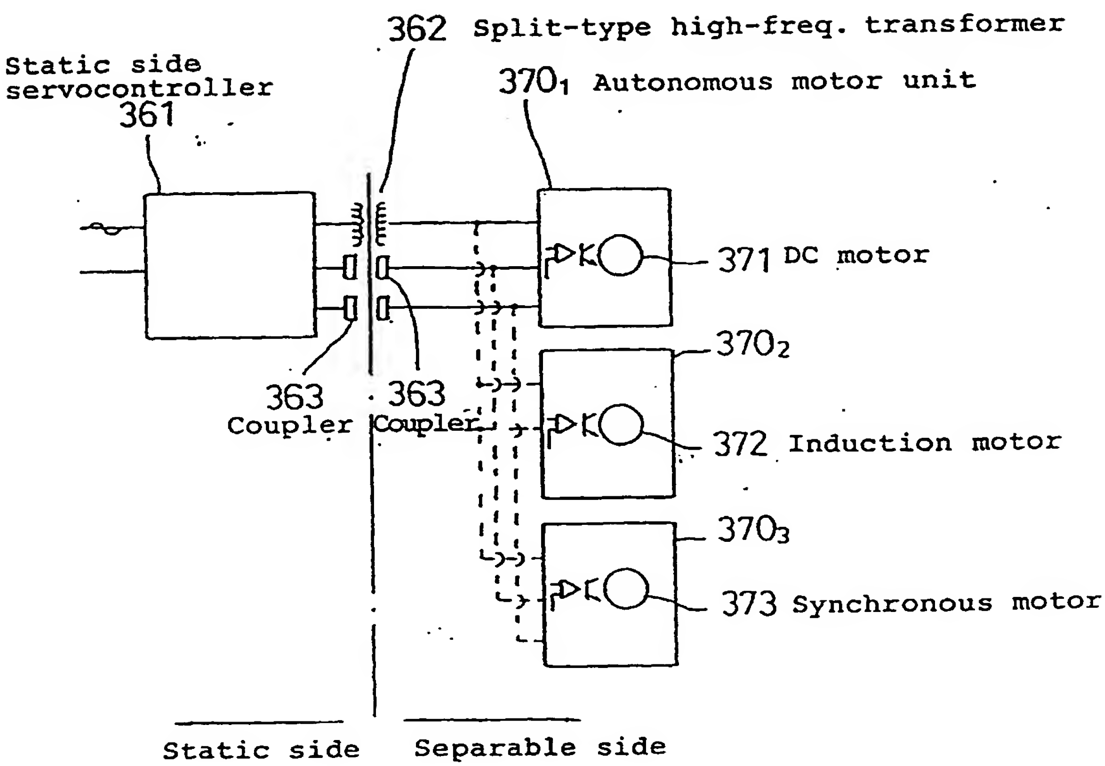

362 Split-type high-freq. transformer
Static side servocontroller
361
370₁ Autonomous motor unit
371 DC motor
370₂
363
Coupler
363
Coupler
372 Induction motor
370₃
373 Synchronous motor
Static side
Separable side

Fig. 32

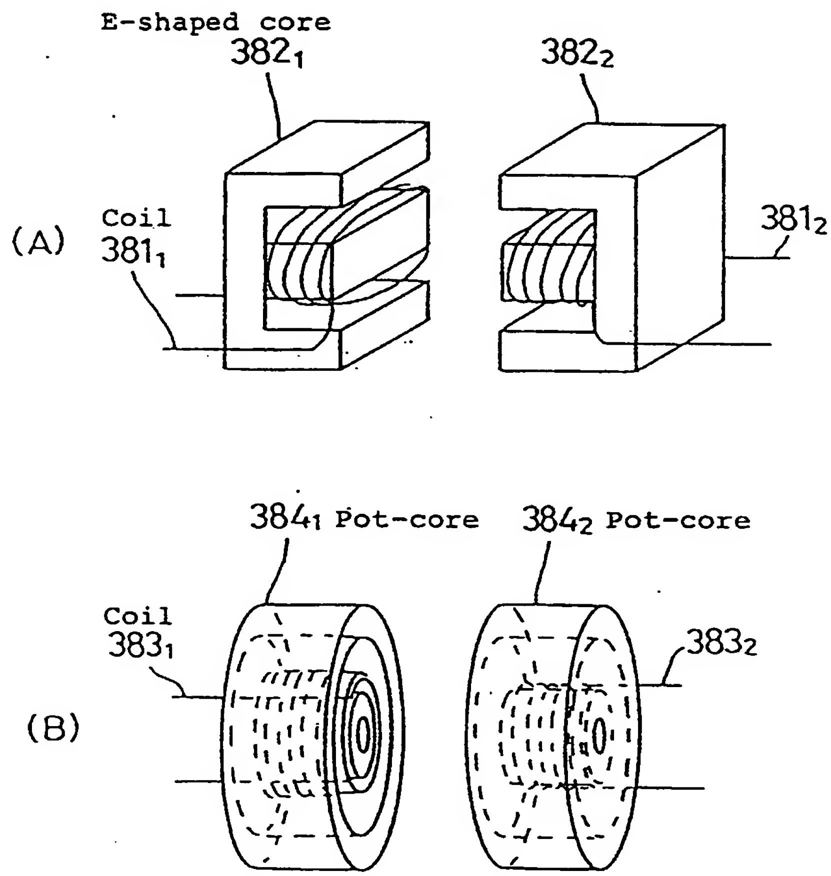

E-shaped core
382_1
382_2
Coil
381_1
(A)
381_2
384_1 Pot-core
384_2 Pot-core
Coil
383_1
(B)
383_2

Fig. 33

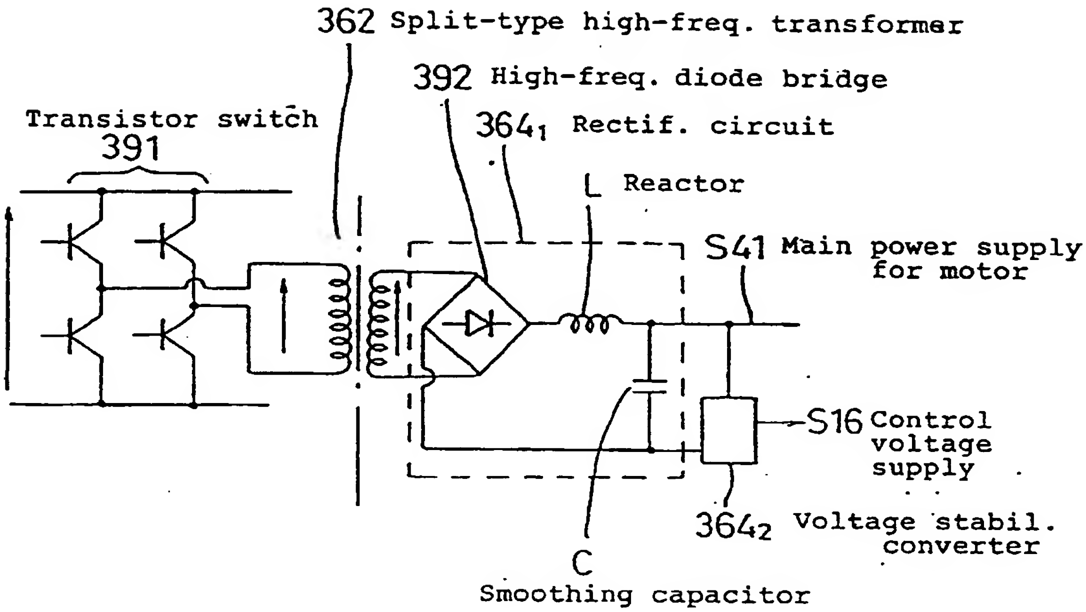

362 Split-type high-freq. transformer
392 High-freq. diode bridge
Transistor switch
391
364₁ Rectif. circuit
L Reactor
S41 Main power supply for motor
S16 Control voltage supply
364₂ Voltage stabil. converter
C
Smoothing capacitor

Fig. 34

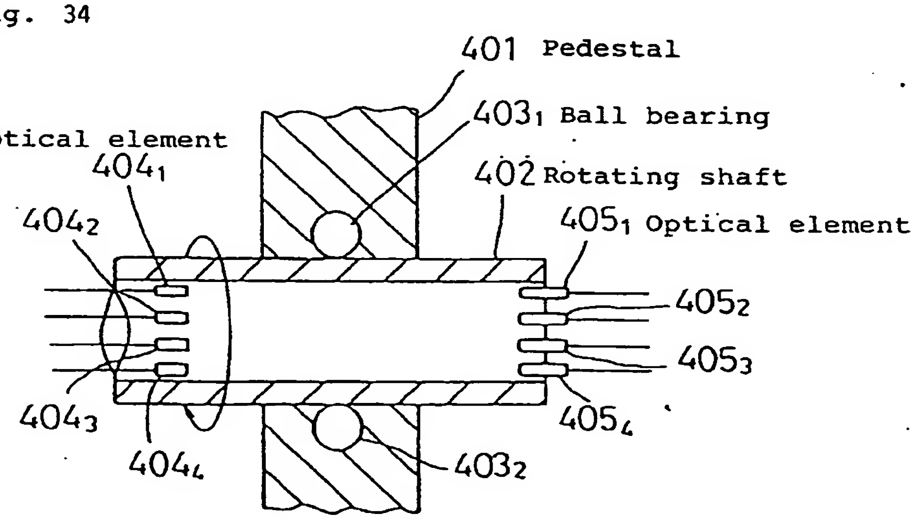

401 Pedestal
403₁ Ball bearing
Optical element
404₁
402 Rotating shaft
404₂
405₁ Optical element
405₂
405₃
404₃
405₄
404₄
403₂

Fig. 35

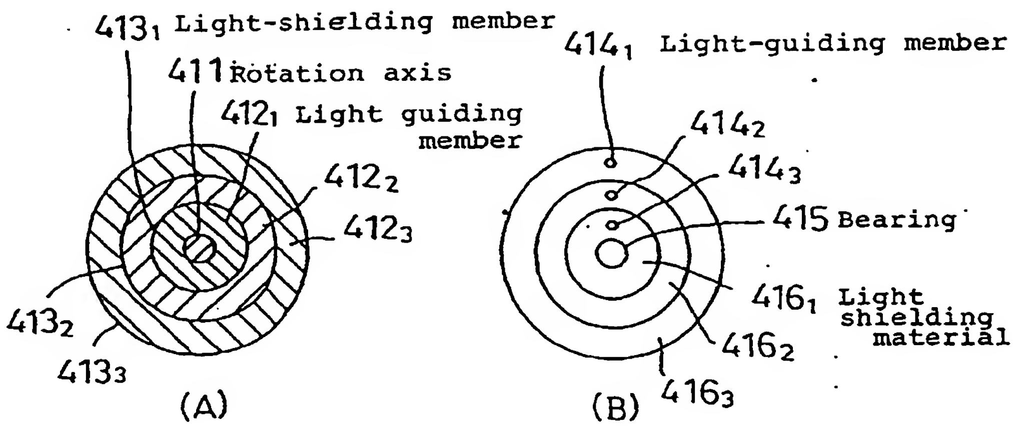
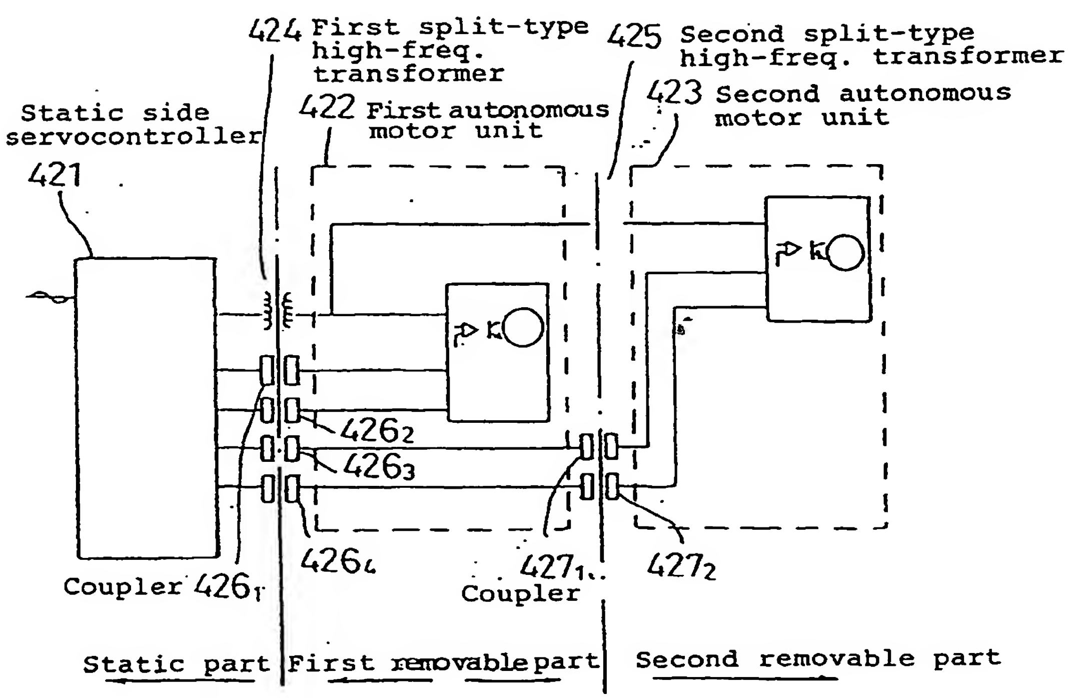

413₁ Light-shielding member
411 Rotation axis
412₁ Light guiding member
412₂
412₃
413₂
413₃
(A)
414₁ Light-guiding member
414₂
414₃
415 Bearing
416₁ Light shielding material
416₂
416₃
(B)

Fig. 36


424 First split-type high-freq. transformer
425 Second split-type high-freq. transformer
423 Second autonomous motor unit
422 First autonomous motor unit
Static side servocontroller
421
426₂
426₃
426₄
427₁
427₂
Coupler 426₁
Coupler
Static part
First removable part
Second removable part